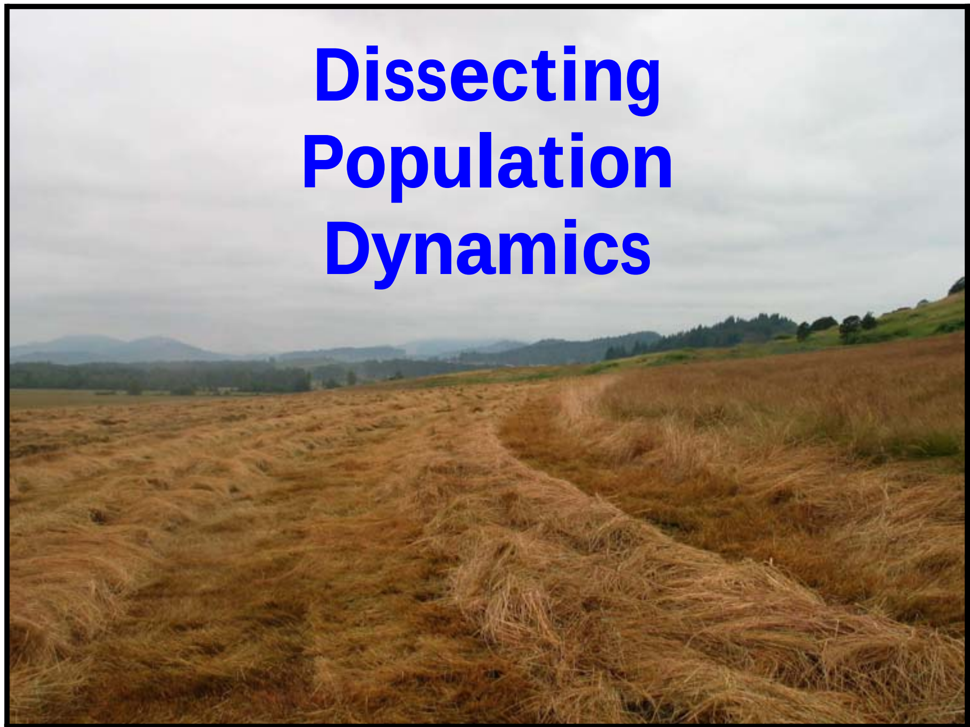
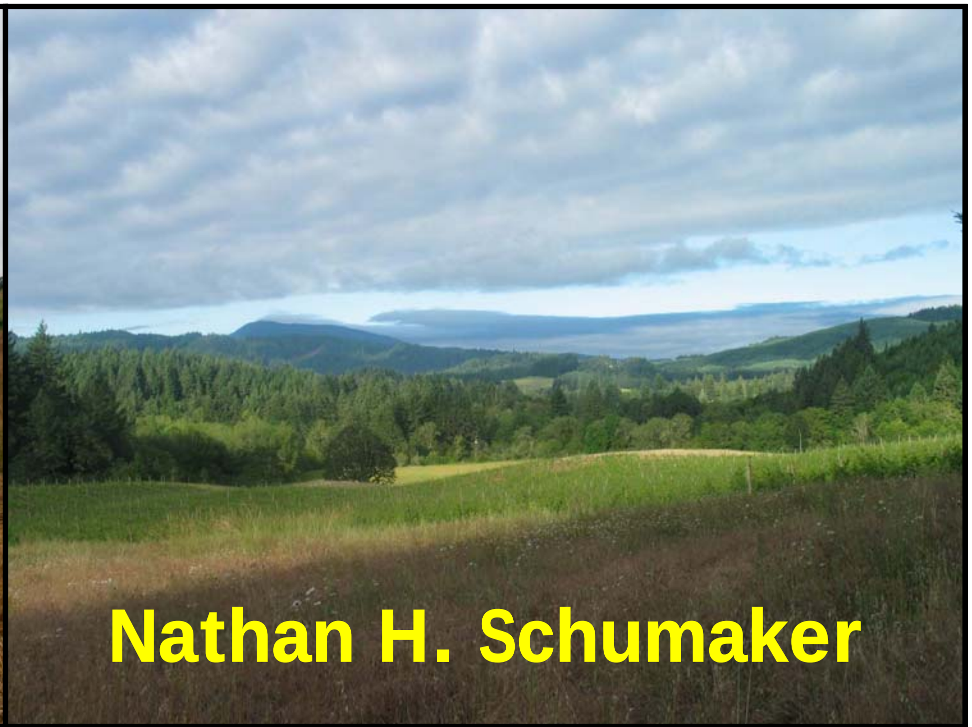
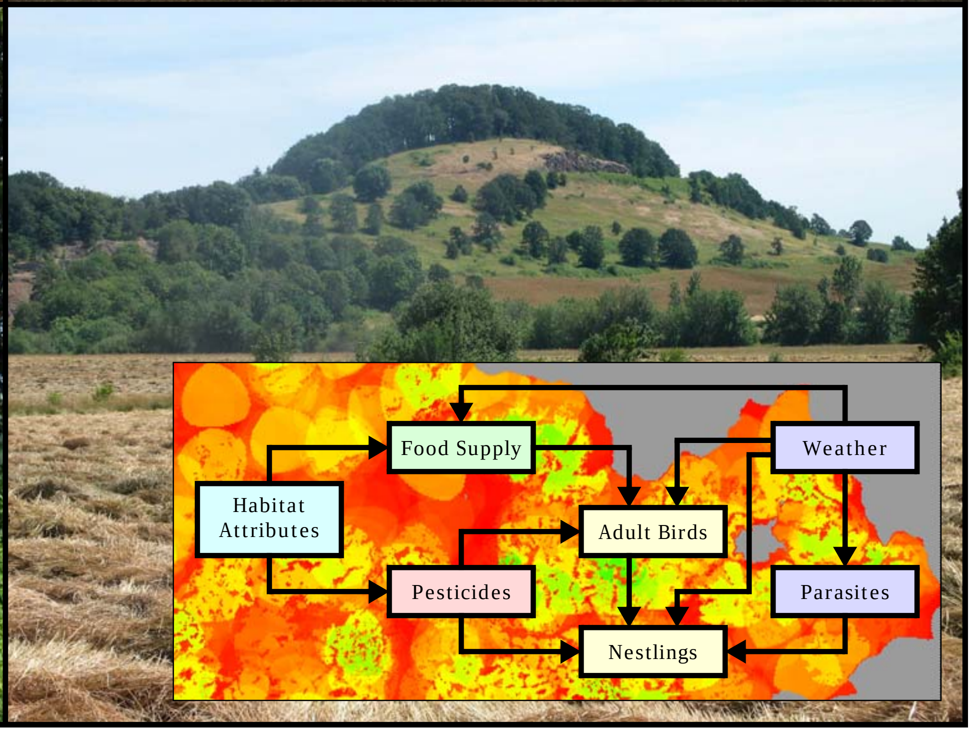
Dissecting Population Dynamics

Nathan H. Schumaker







Introduction

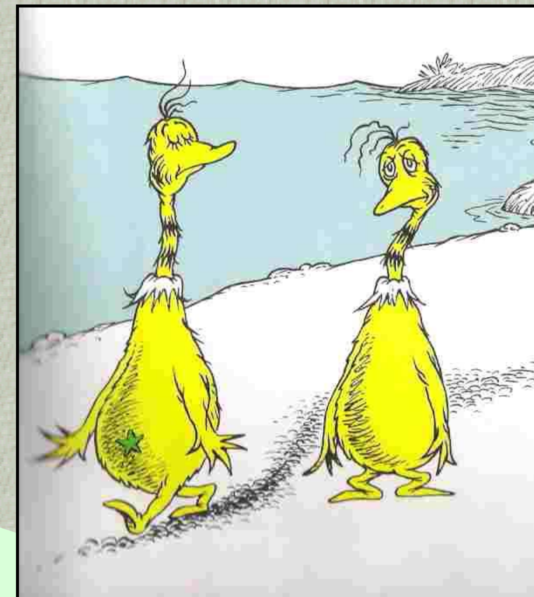
Today's seminar will explore why

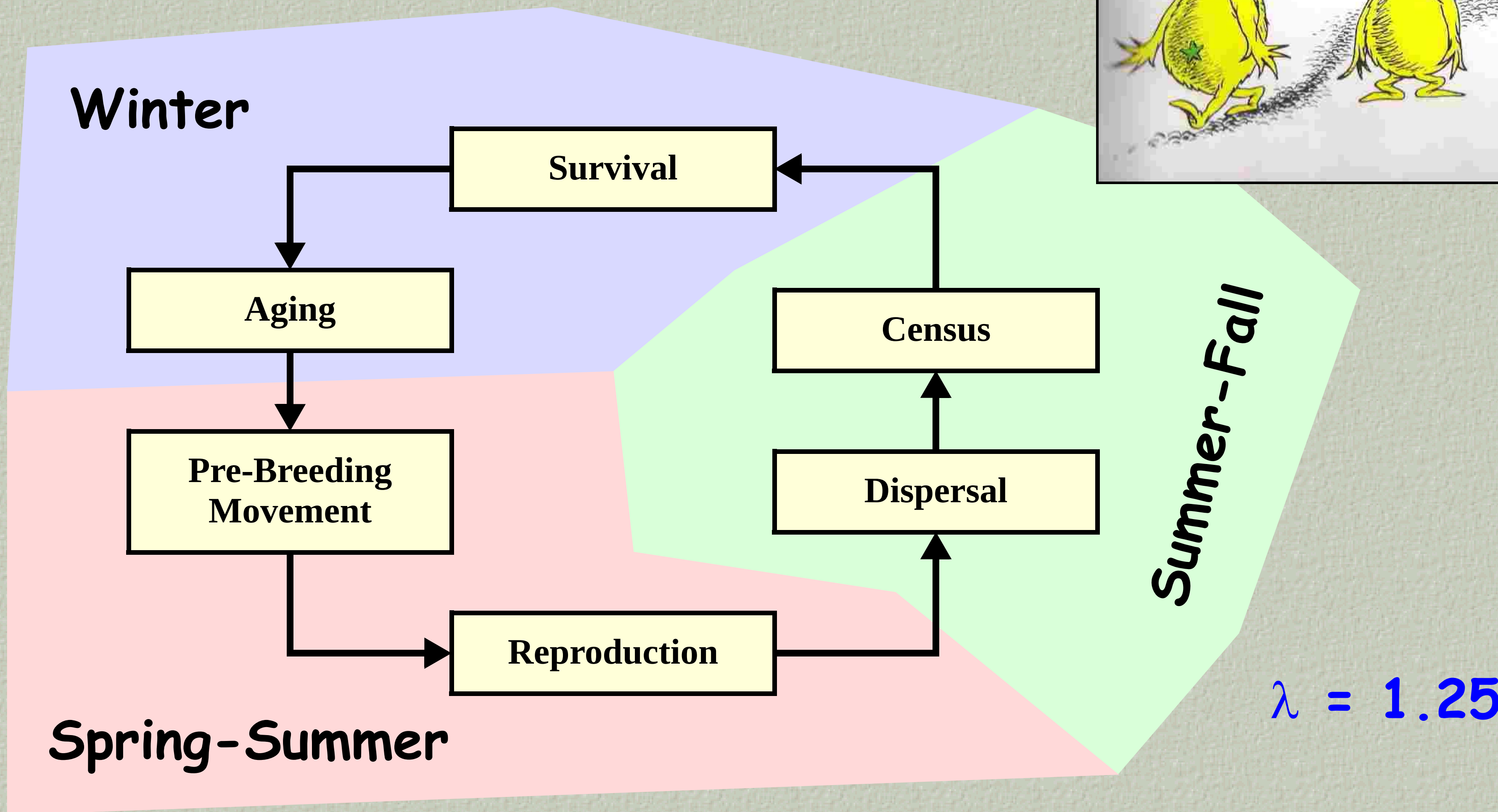
space matters

from two different angles:

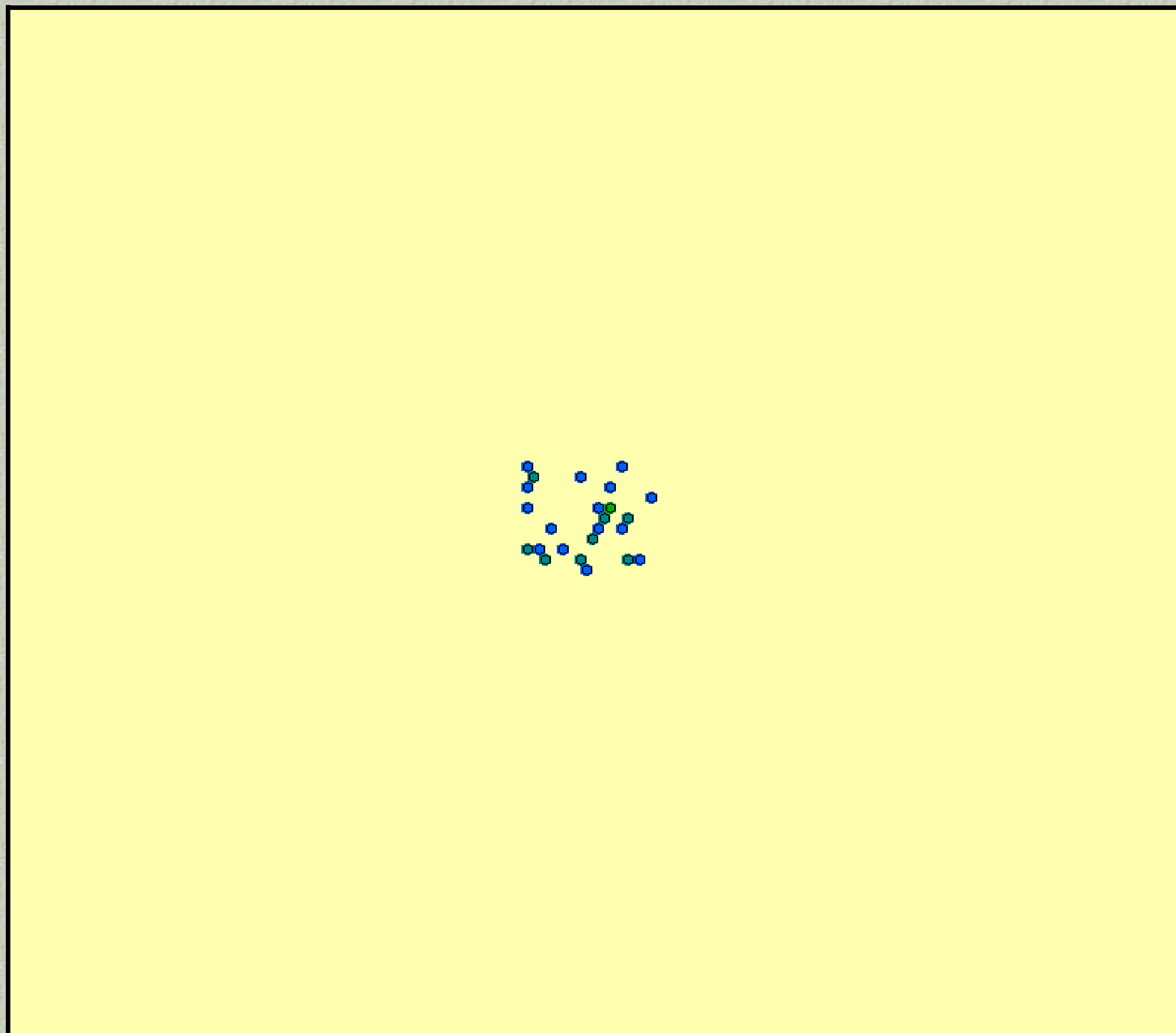
- **By examining some simple contrasts between spatial simple vs. complex wildlife models**
- **By exploring links between habitat quality, landscape structure, and population dynamics**

Start With A Simple Life History:
The Sneetch

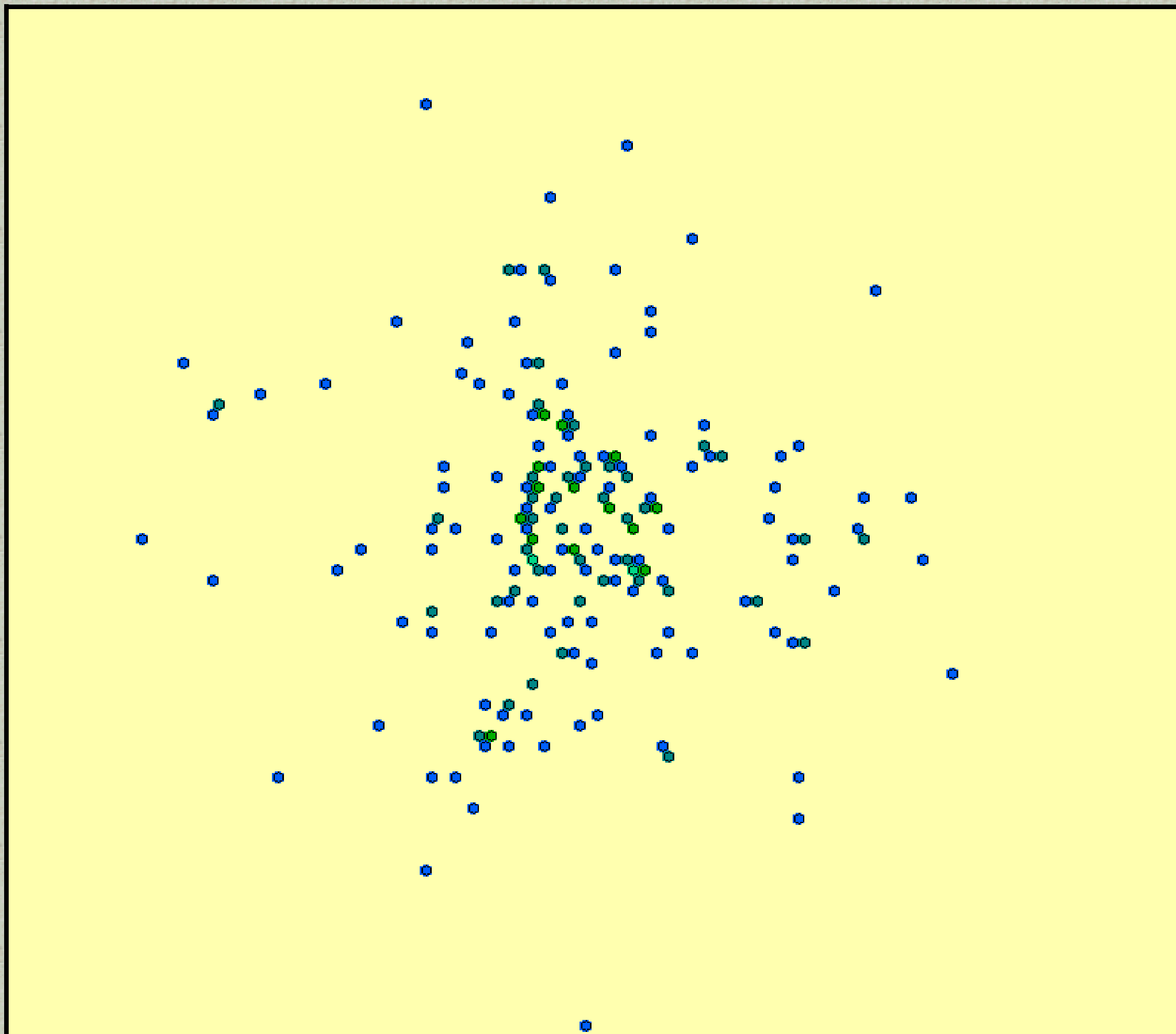




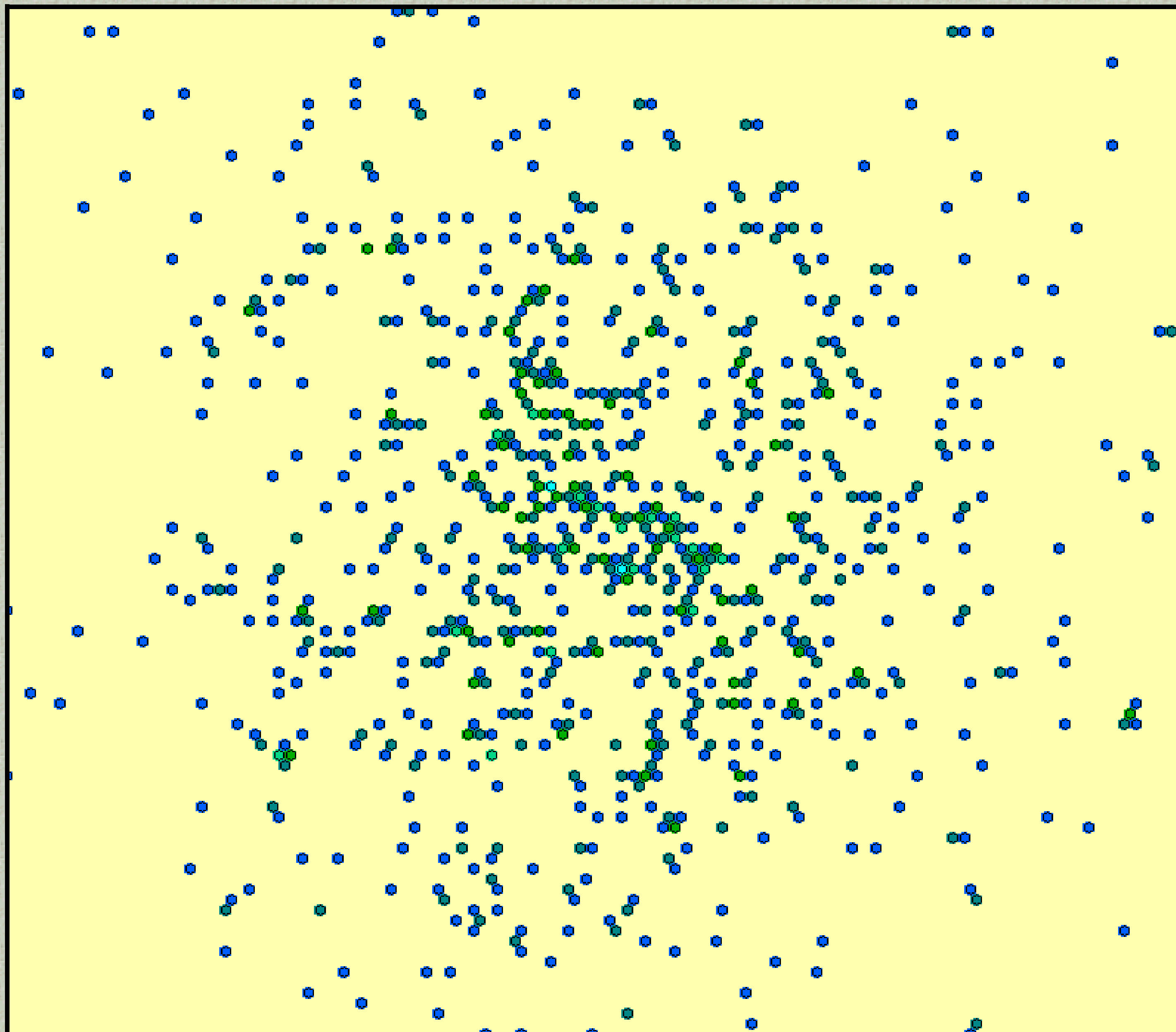
Let A Few Sneetches Loose In A Uniform World



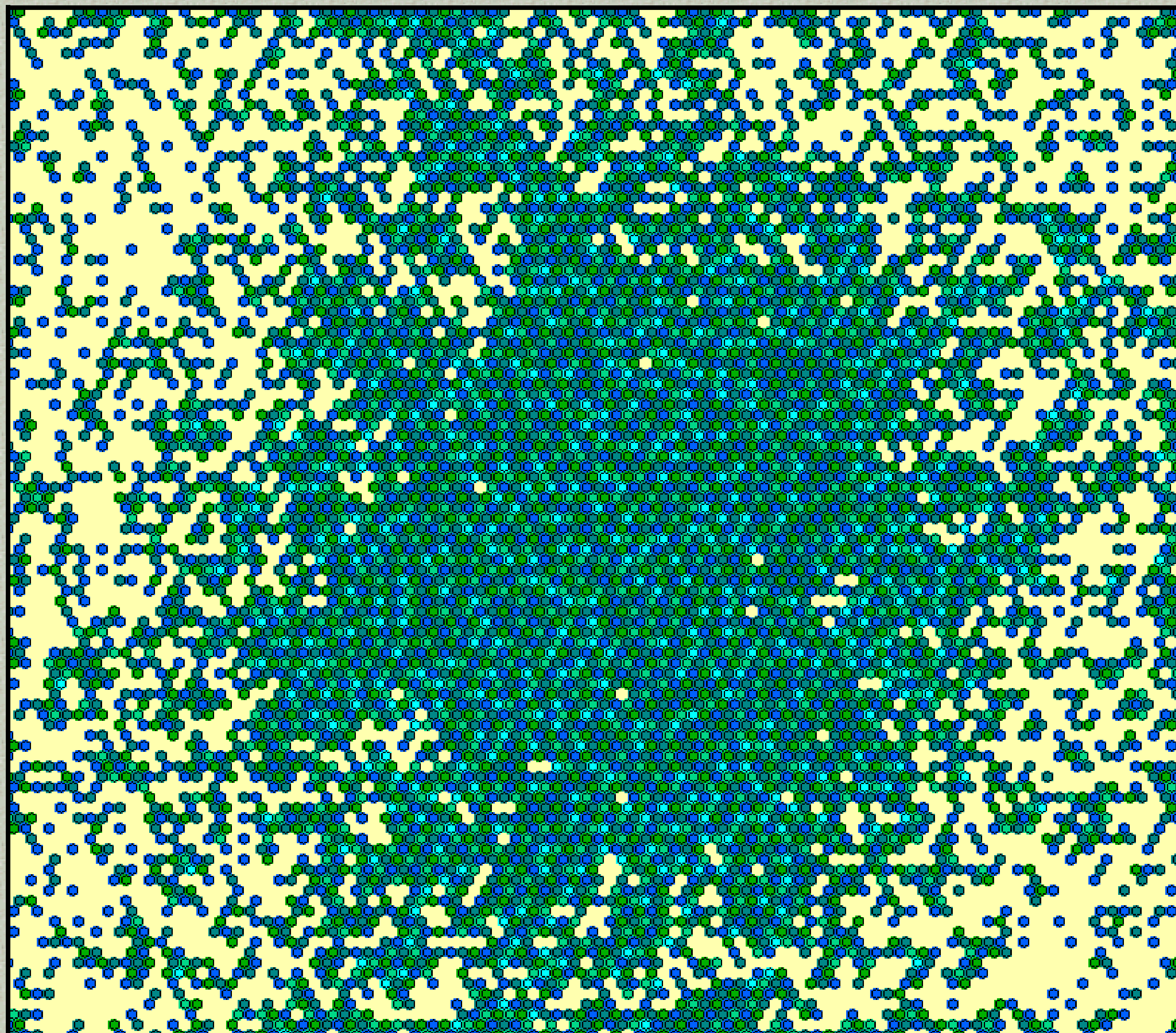
Their Numbers Will Grow

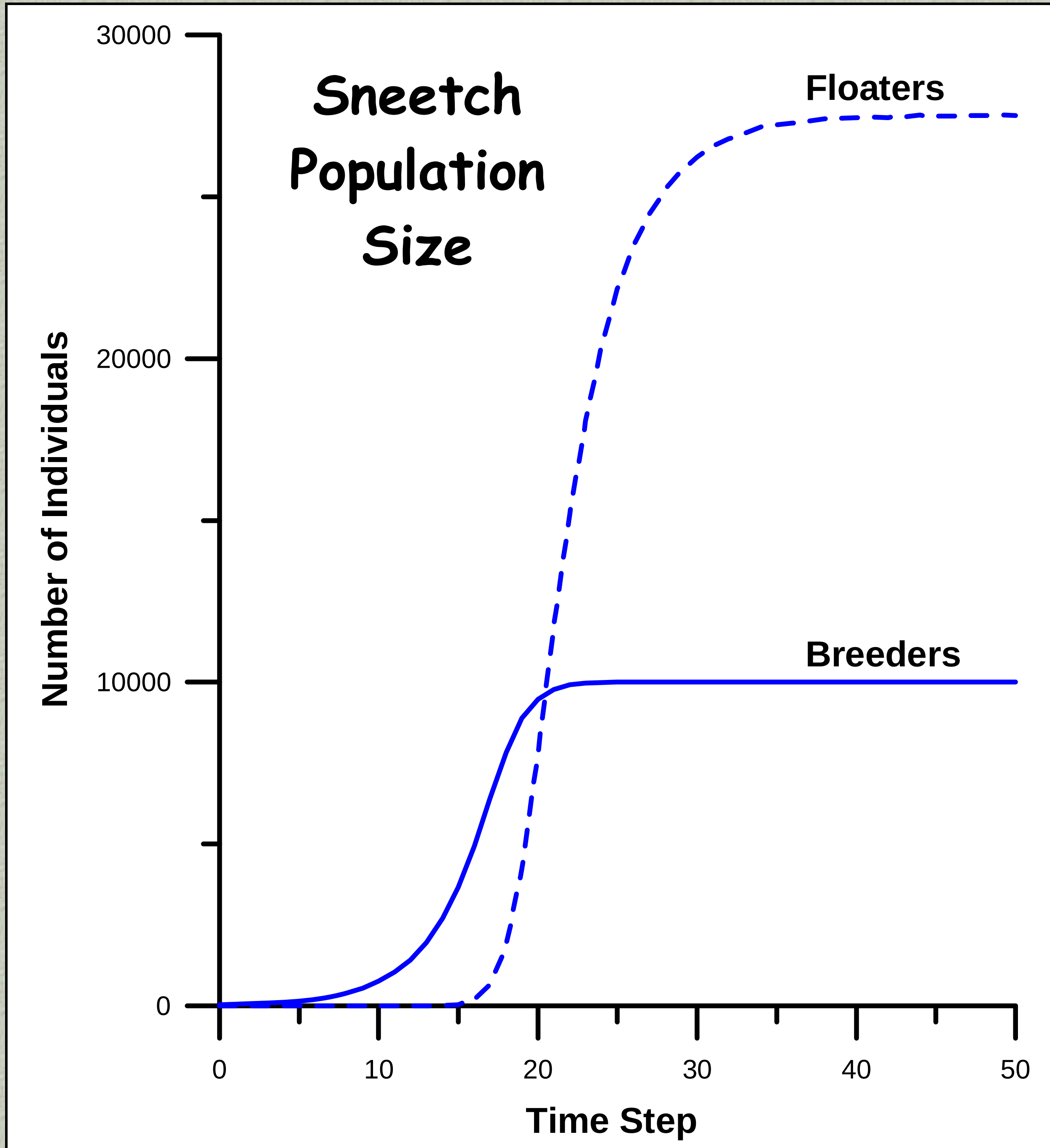


And Grow...



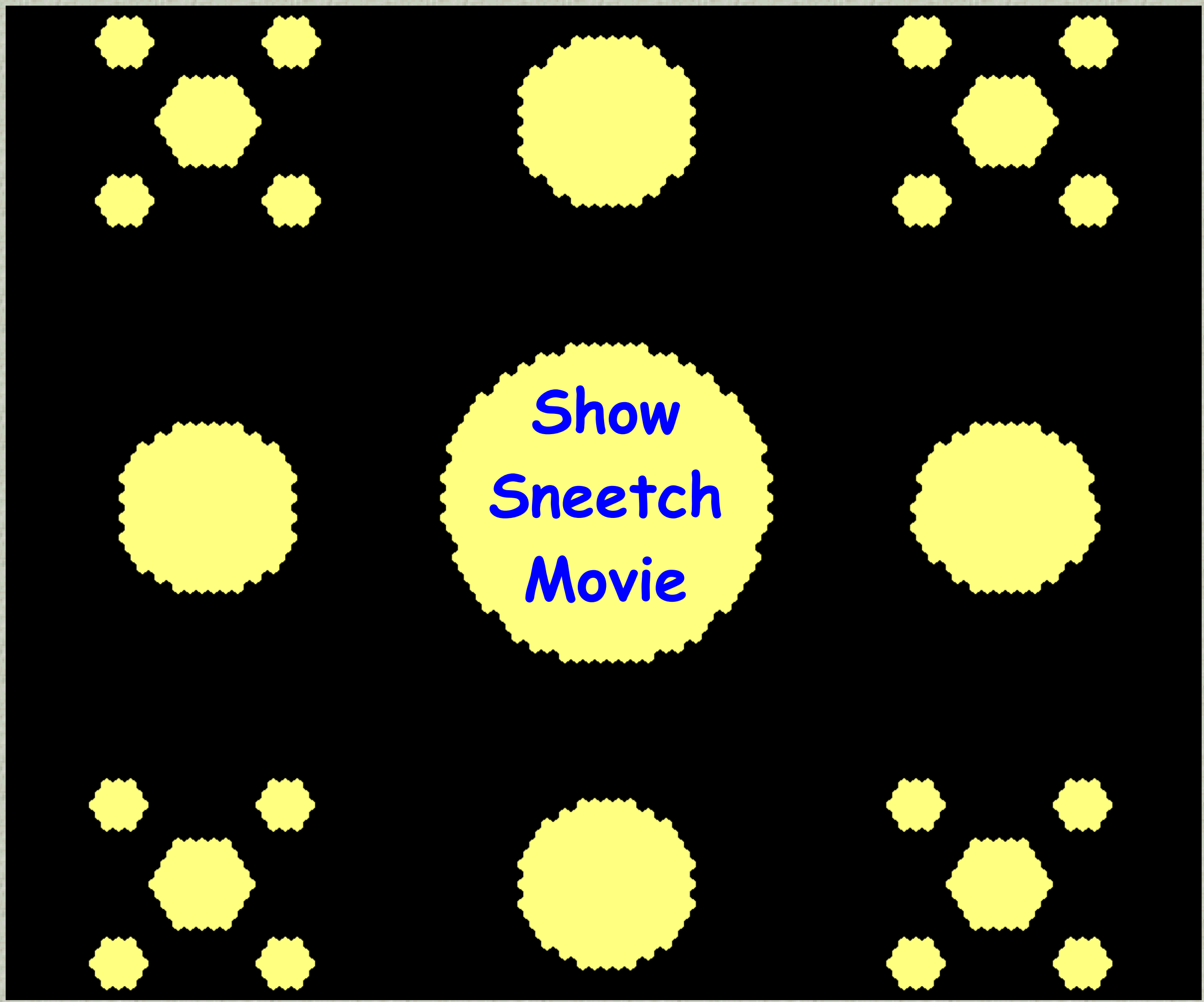
With Sneetches Soon Filling The Available Space





Sneetch Population Size
Floaters
Breeders
30000
20000
10000
0
0
10
20
30
40
50
Number of Individuals
Time Step

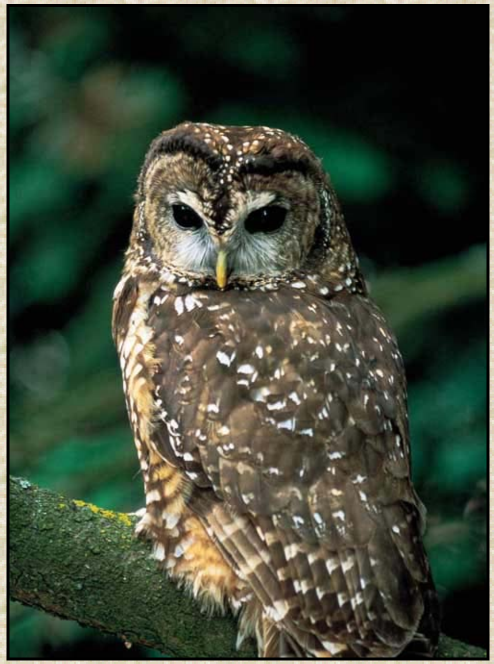
The Actual Sneetch World Is Spatially Complex
What Impact Does This Have On Their Dynamics ??



In spite of their limited dispersal ability (most Sneetches are short-distance dispersers) their high growth (λ = 1.25) rate allows the population to rapidly colonize all available habitat...

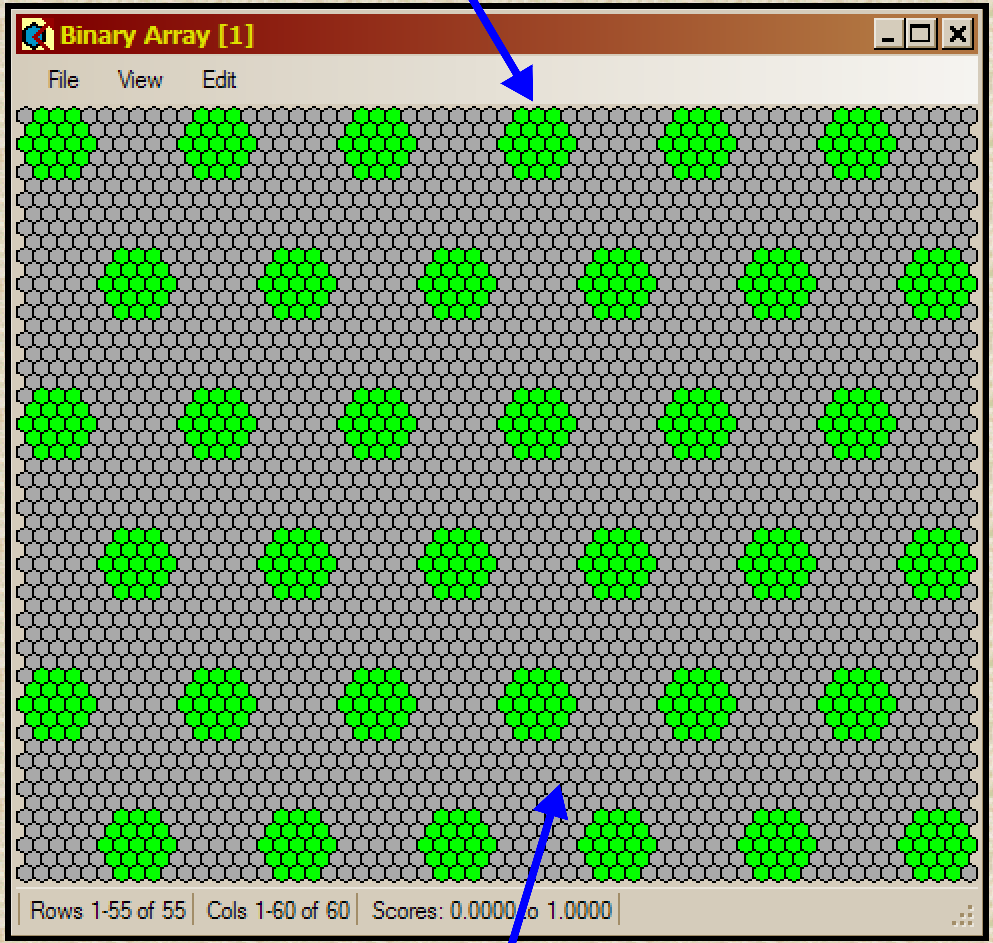
A Real-World Example

Northern Spotted Owl
(Strix occidentalis caurina)



- **A threatened species in the U.S.**
- **Population is declining. Solution is highly controversial**
- **Key issue is how spatial pattern influences population viability**

Habitat patches are all equal



Owls cannot survive in the matrix

Spotted Owl Reserve Design

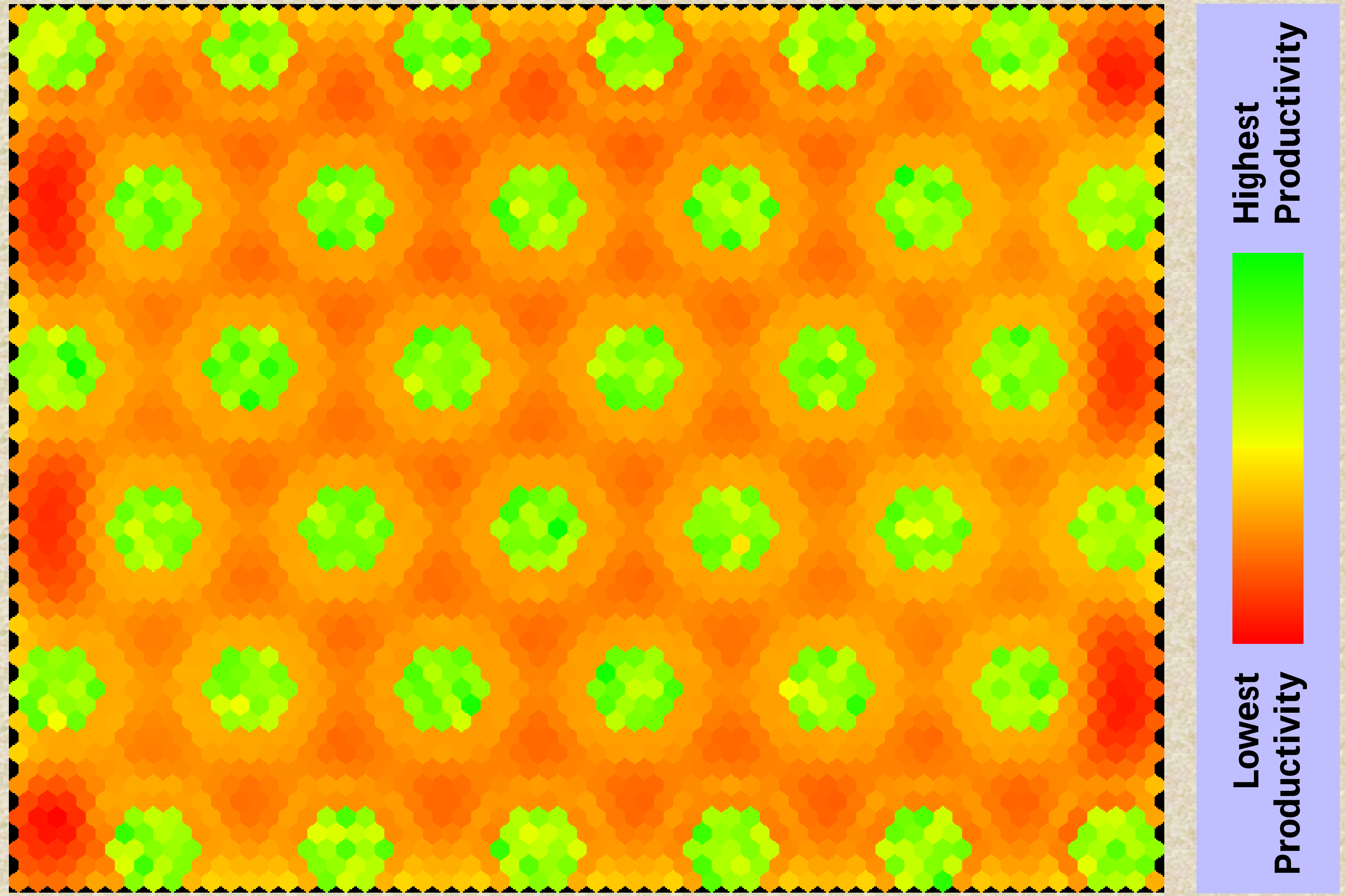
This shows a hypothetical spotted owl habitat array with specific reserve size and spacing

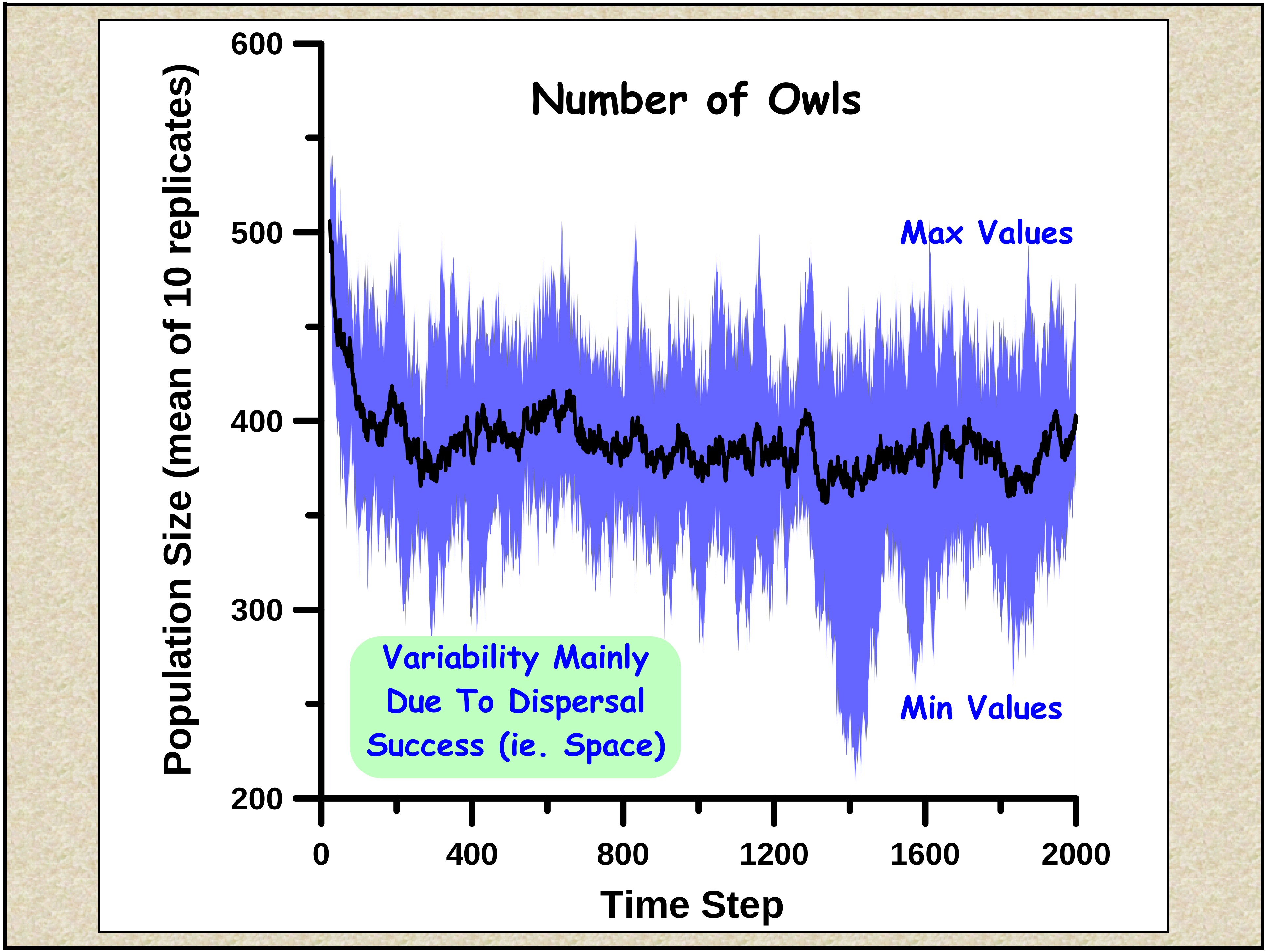
How Will the Owls Do ??

Some data indicate that Lambda is slightly greater than 1.0

- **Thus the population *should* remain stable**
- **But what about dispersal success rates, and the impact of non-breeding floaters ?**

Observed Owl Productivity (births - deaths)





Number of Owls
Population Size (mean of 10 replicates)
600
500
400
300
200
0
400
800
1200
1600
2000
Time Step
Max Values
Min Values
Variability Mainly Due To Dispersal Success (ie. Space)

How Was Owl Performance ??

[Final 1000 Years, Averaged Over 10 Replicates]

$$\text{Input Matrix} = \begin{bmatrix} 0.078 & 0.192 & 0.348 & 0.348 \\ 0.333 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.760 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.850 & 0.920 \end{bmatrix} \quad \lambda = 1.013$$

$$\text{Output Matrix} = \begin{bmatrix} 0.077 & 0.192 & 0.349 & 0.348 \\ 0.290 & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.756 & 0.000 & 0.000 \\ 0.000 & 0.000 & 0.849 & 0.920 \end{bmatrix} \quad \lambda = 1.001$$

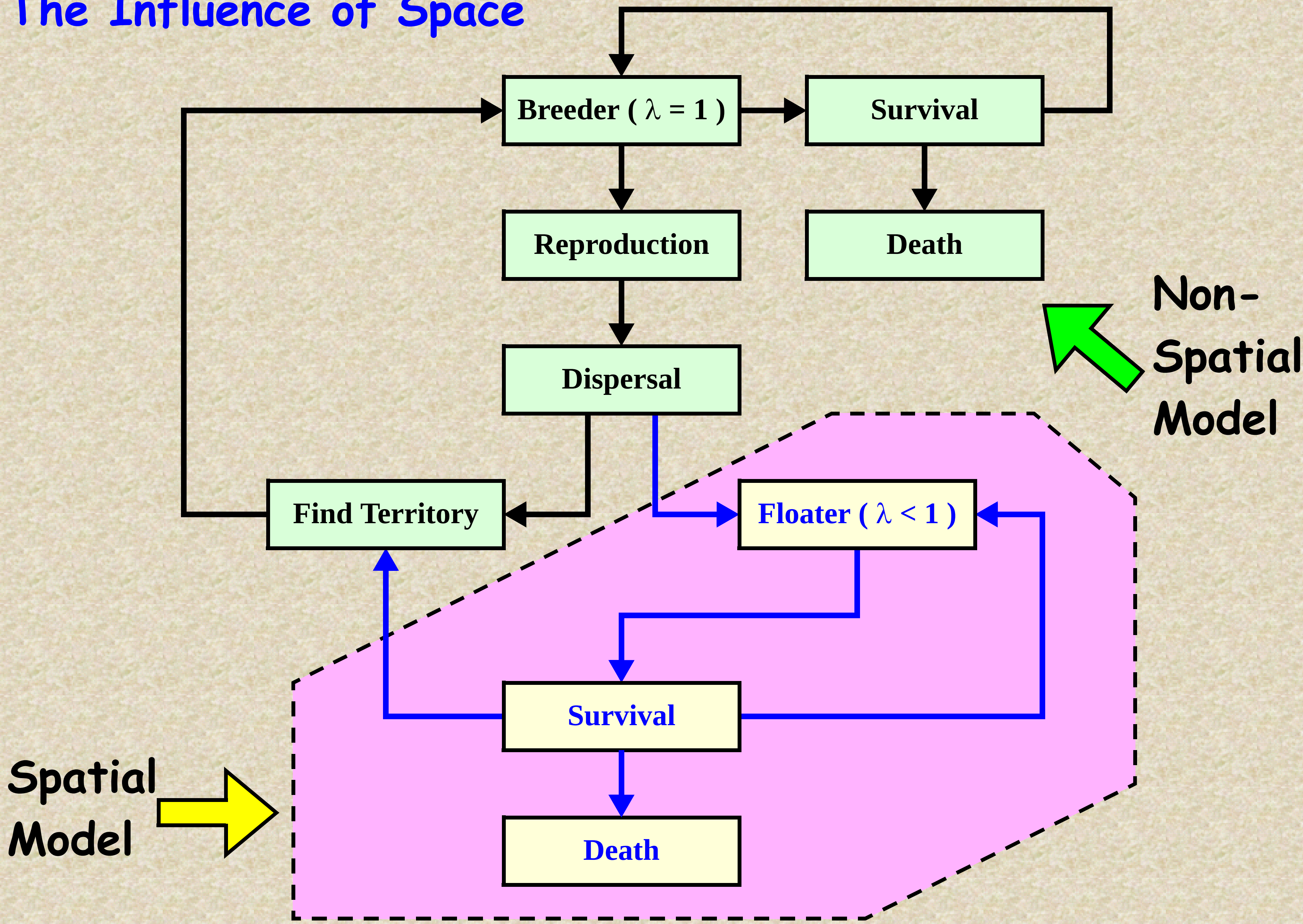
Lowered Survival Due To Dispersal Success (ie. Space)

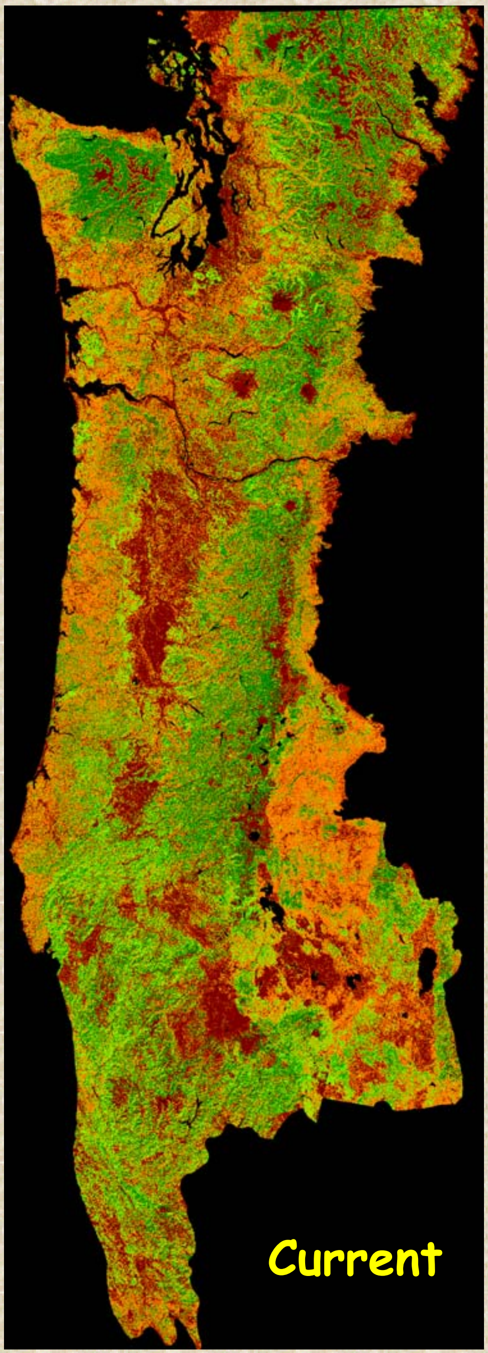
Carrying Capacity = 684

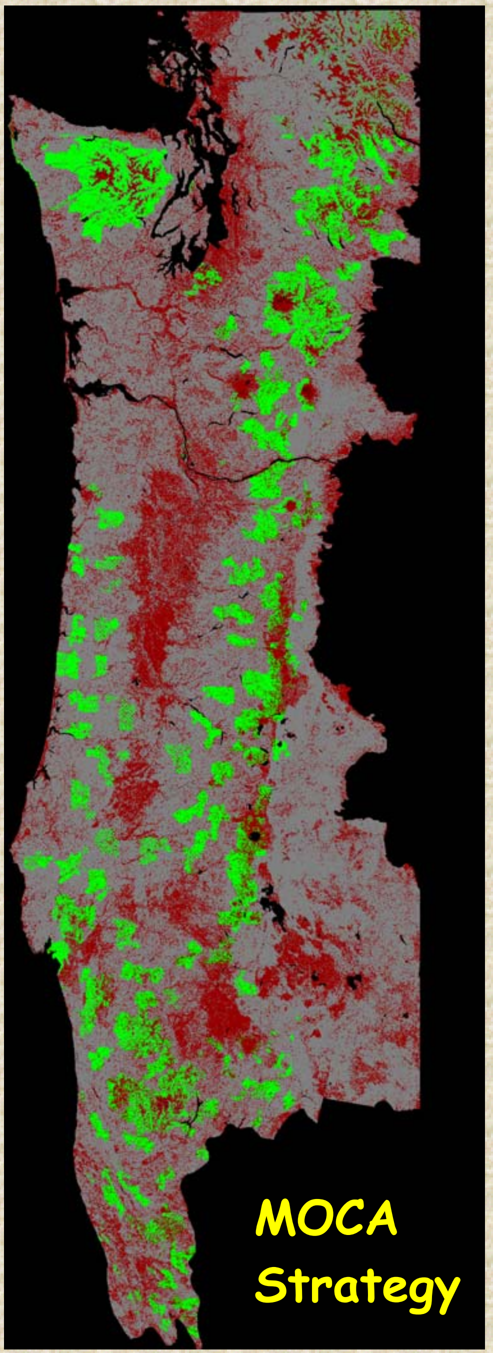
Mean Population Size = 381

Occupancy Rate = 56%

The Influence of Space







Proposed NSO reserves often do look like an array of habitat clusters in a non-habitat matrix

Its important to anticipate how much of such a landscape will be occupied, and how variable the numbers will be

Another Example Where Space Matters

Ord's Kangaroo Rat (Dipodomys ordii)

- Listed as an endangered species in Alberta, Canada
- Population is declining, and the rate of decline is increasing
- This analysis is being used to develop a PVA for the species

Range of Ord's Kangaroo Rat

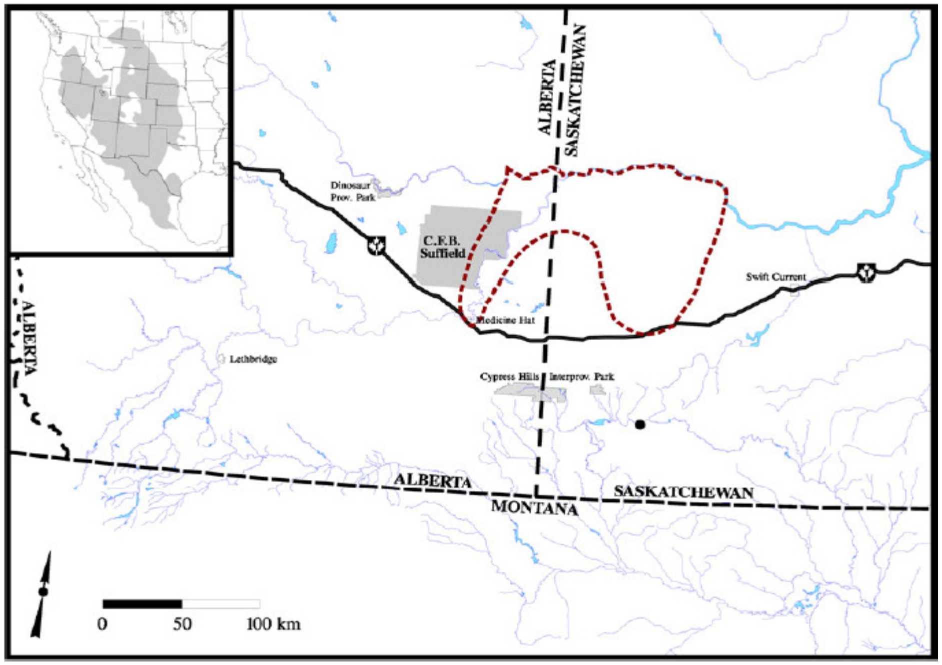


Figure 2. Known range of Ord's kangaroo rats in Canada (Gummer and Robertson 2003). Inset: North American species range (Hall 1981).

From Draft PVA, January 2008

In Alberta, much of the species range is loc[illegible] Forces Base (CFB) Suffield, a large military base near Me[illegible] [illegible]lations occur primarily on the east side of the base, in the S[illegible] [illegible] Area (SNWA) (Figure 3). This refuge was officially designated a p[illegible] [illegible] under the Canadian Wildlife Act in 2003, although it has been off limits to public access and military exercises since 1971 (CFB Suffield 2005).

Habitat Requirements

The Ord's kangaroo rat has highly specific habitat requirements. The species requires open, sparsely vegetated, sandy habitats for the species' hopping style of locomotion and burrowing (Bartholomew and Caswell 1951, Armstrong 1979, Hallett 1982, Kenny 1989, Gummer 1999). In the Middle Sand Hills, natural habitats consist of sandy features such as actively eroding sand dunes or blowouts, and semi-stabilized or stabilized sand dunes (Figure 4). To a lesser extent, kangaroo rats also occupy eroded slopes of glacial or fluvial origin. K[illegible] rats are also found in areas where sand is exposed by human activities (Ne[illegible] Smith and Hampson 1969, Kaufman and Kaufman 1982, Sta[illegible] 997a, Gummer 1999, Bender et al. 2005). Such anthr[illegible] roads, trails, plowed fireguards, bare ground associated with [illegible] and the margins of cultivated agricultural lands (COSEWIC 2006).

From Draft PVA, January 2008

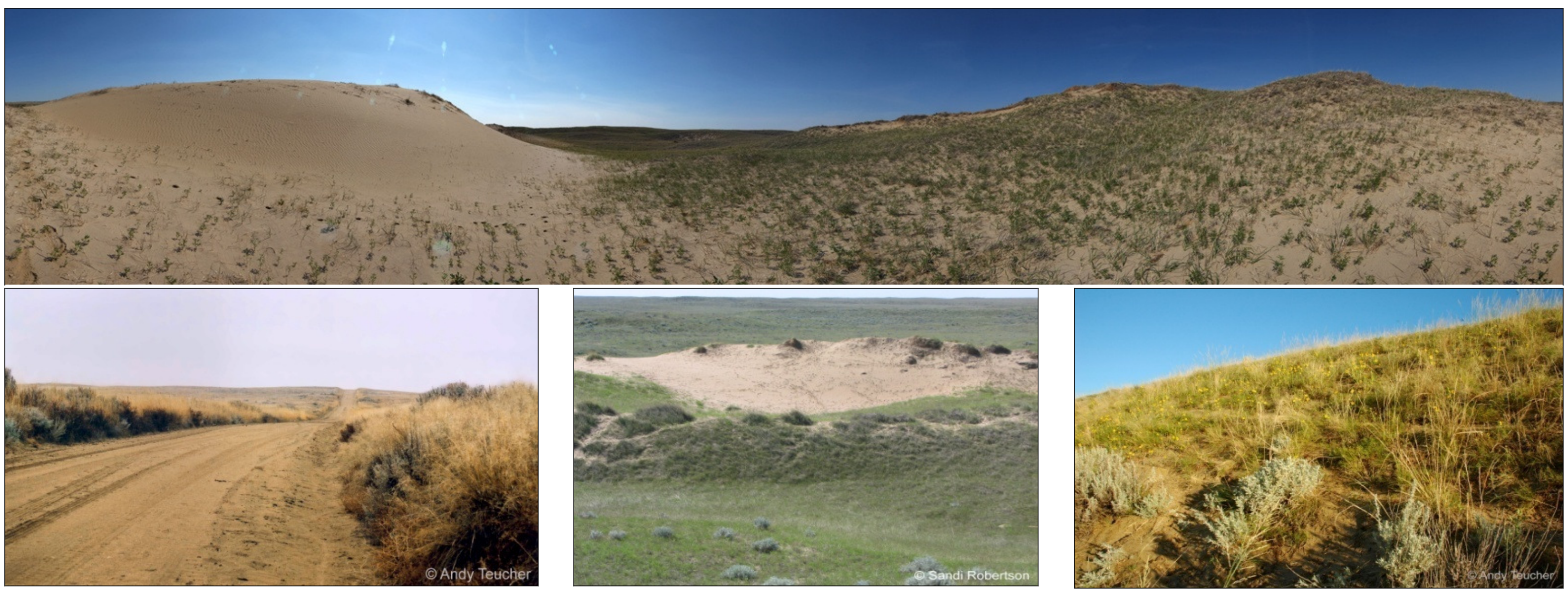
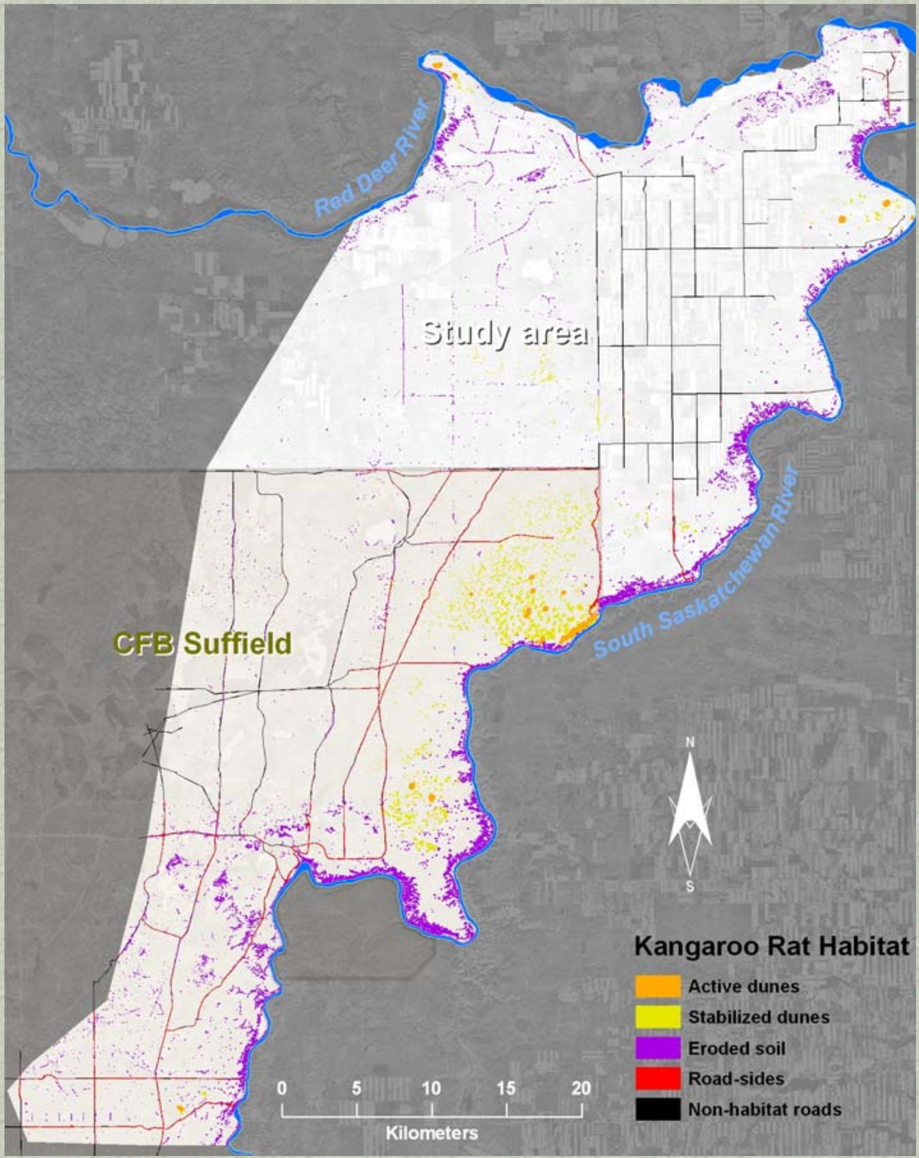
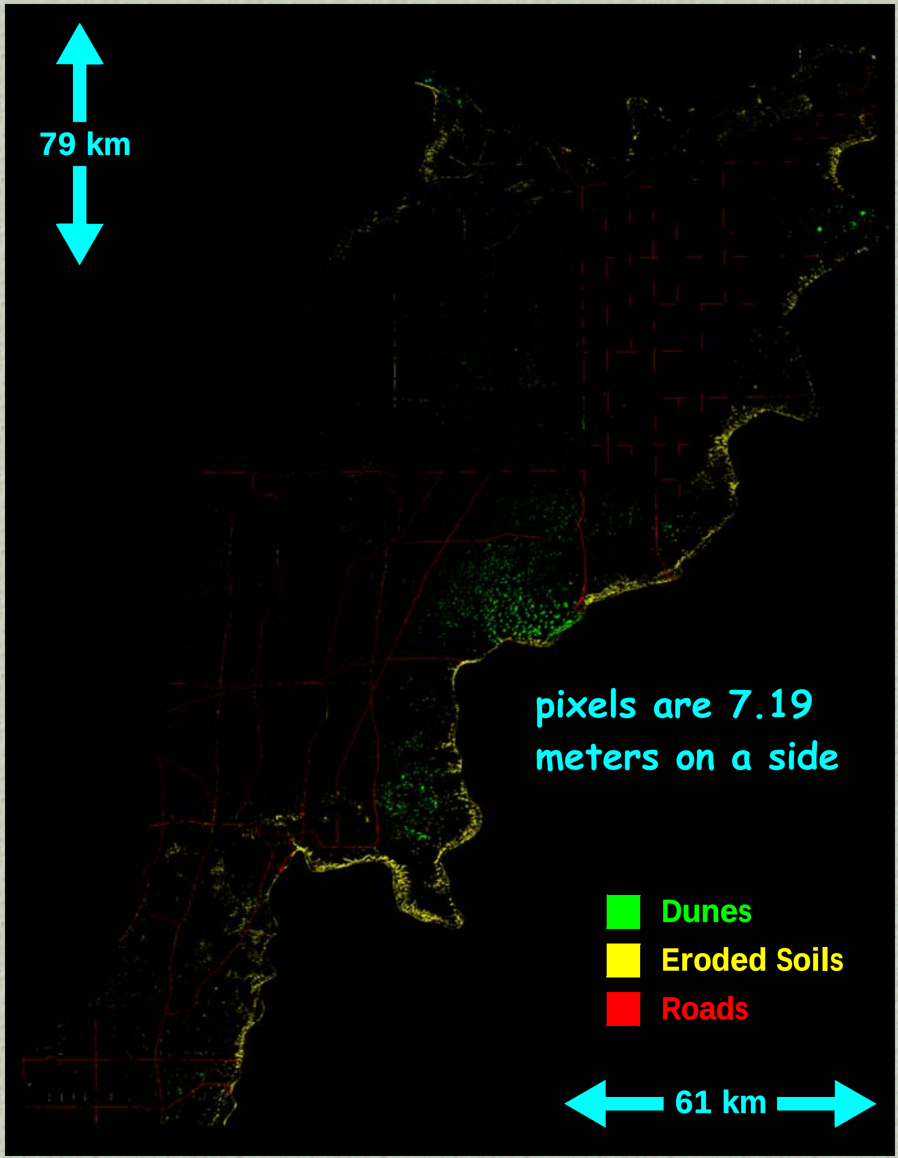


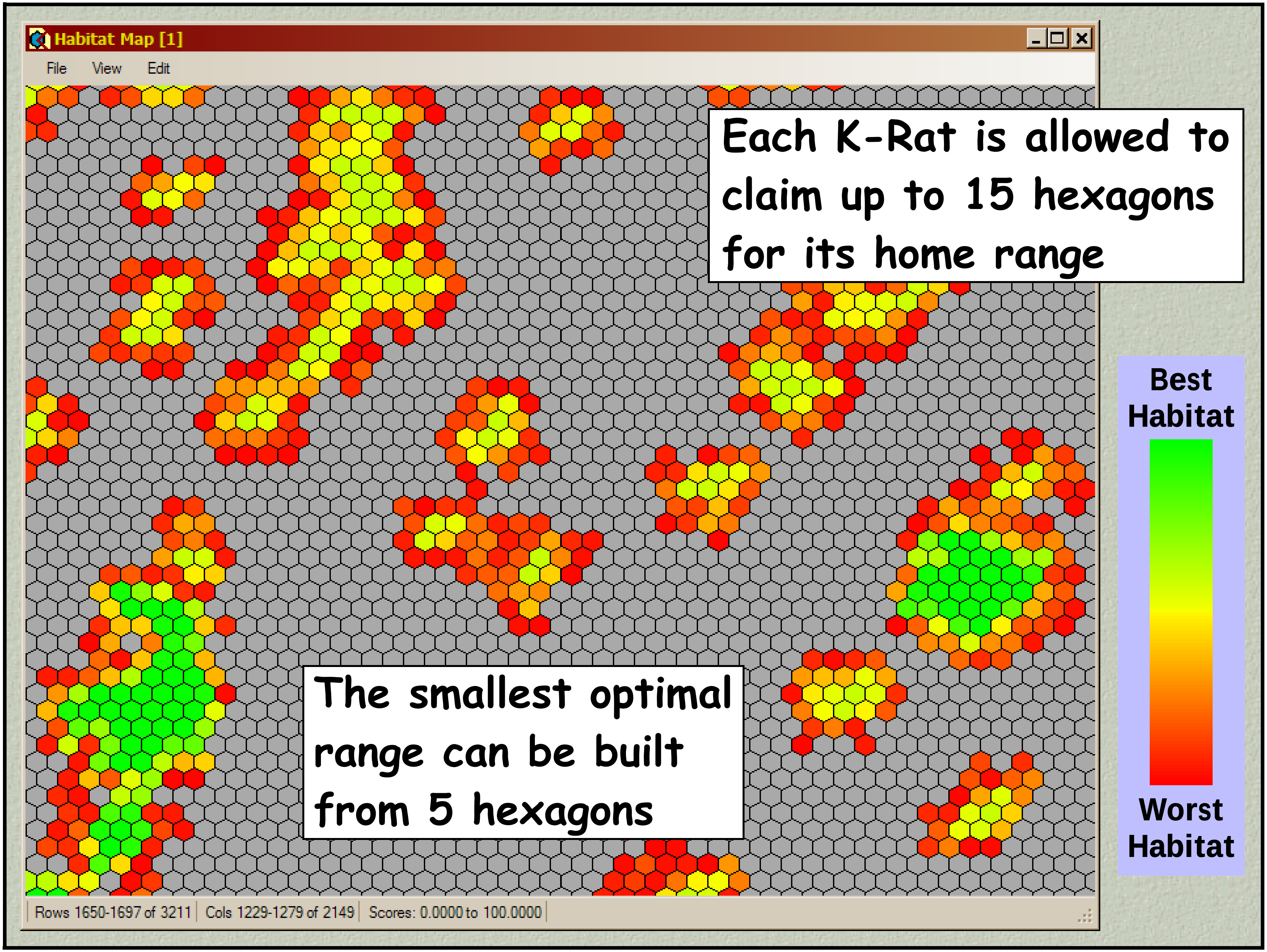
Figure 4. Top: Active sand dune; Bottom Left: A sandy road doubling as a fireguard; Bottom Centre: Sandy blowout; Bottom Right: Partially vegetated slope along a river valey.

Study Area (From Draft PVA)

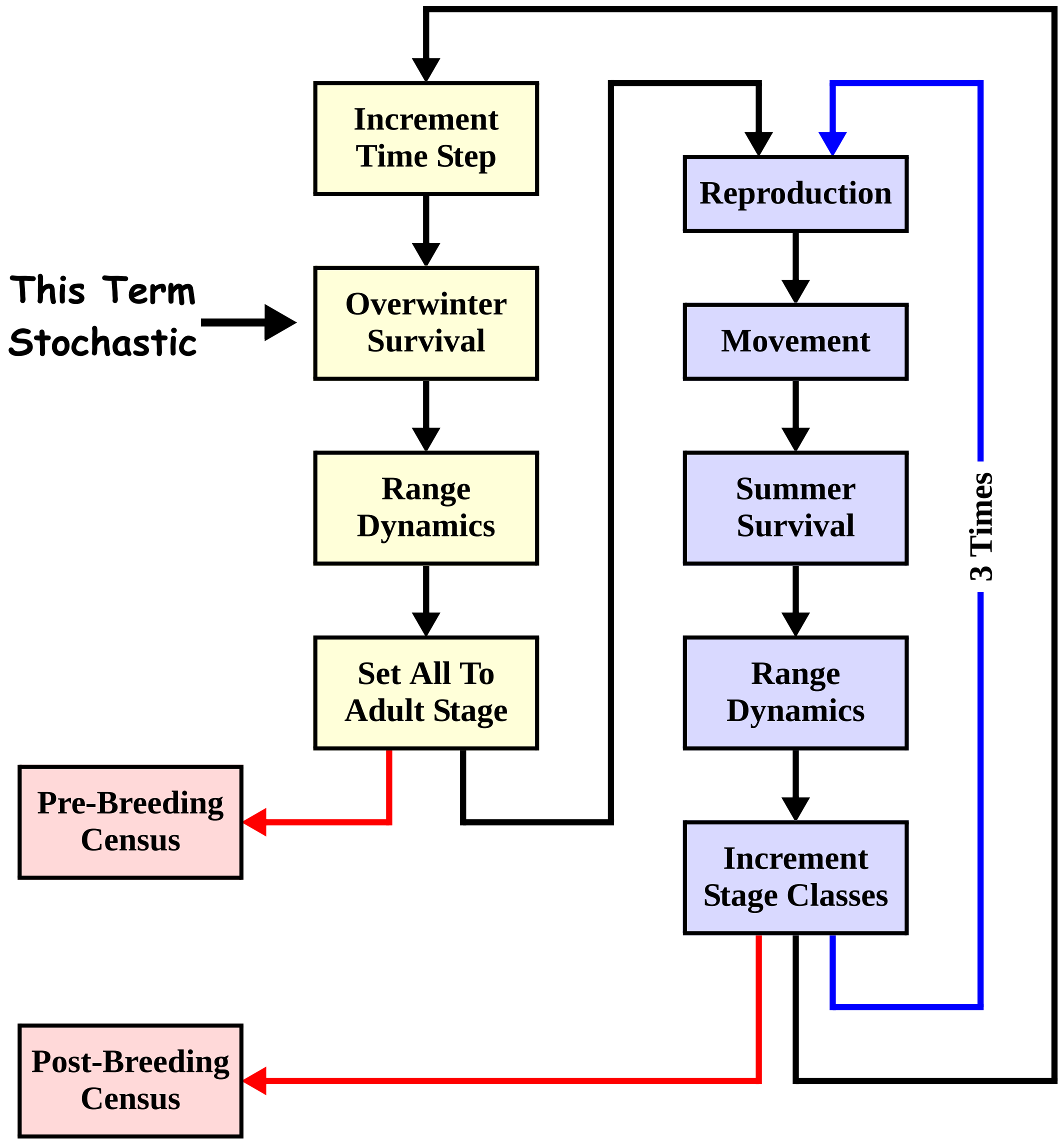


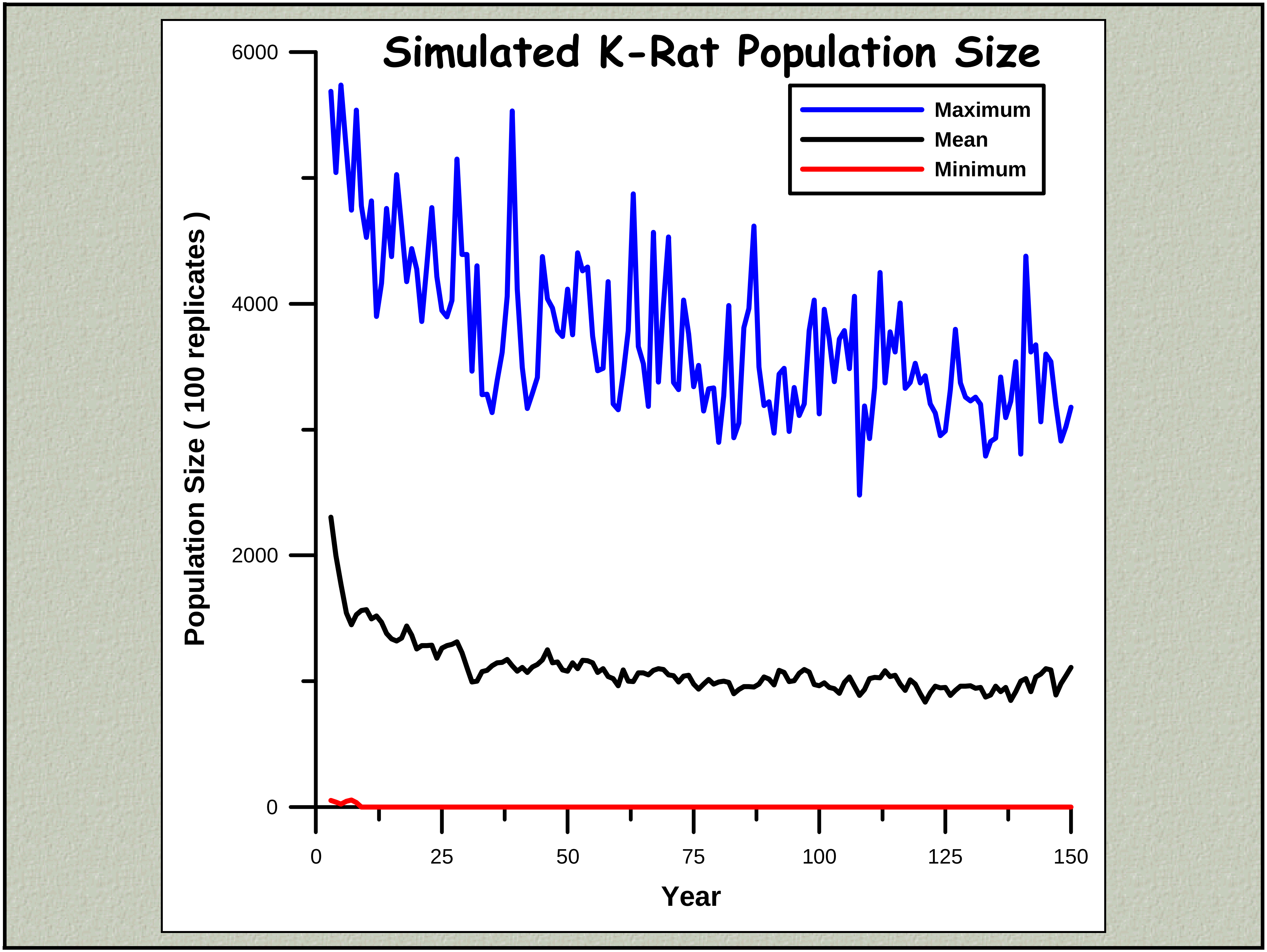
Raster K-Rat Habitat Map (Model Input)



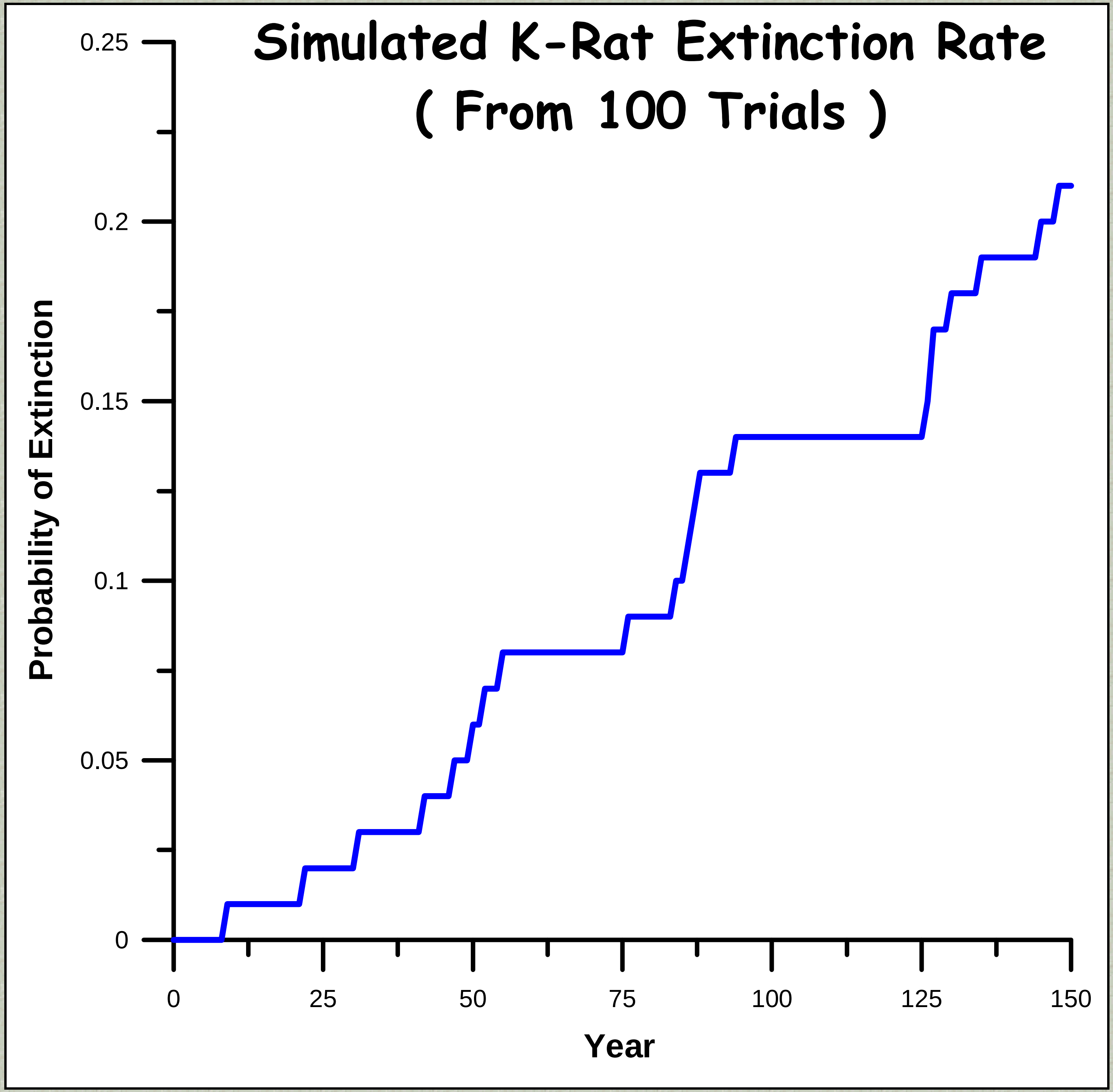

Habitat Map [1]
File
View
Edit
Each K-Rat is allowed to claim up to 15 hexagons for its home range
The smallest optimal range can be built from 5 hexagons
Rows 1650-1697 of 3211
Cols 1229-1279 of 2149
Scores: 0.0000 to 100.0000
Best Habitat
Worst Habitat

Kangaroo Rat Life Cycle
Implemented in HexSim

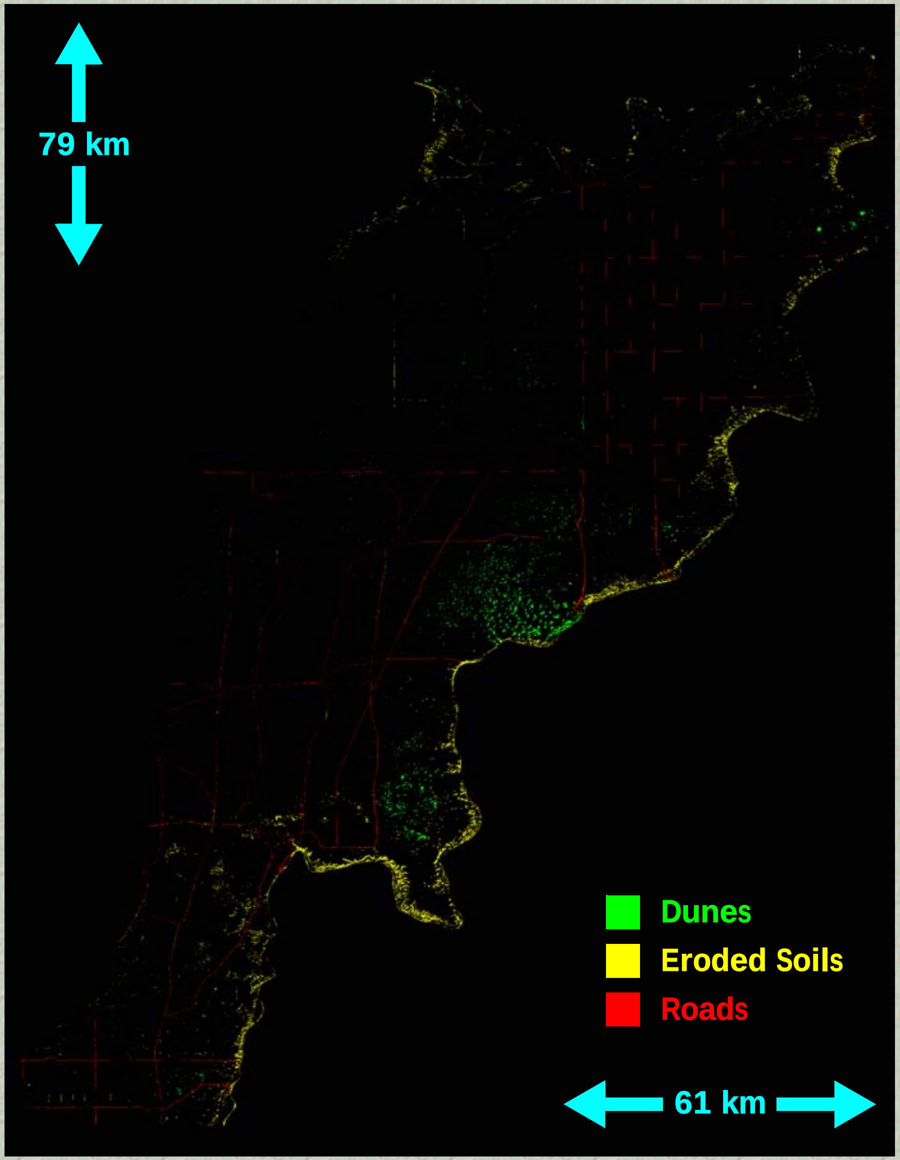




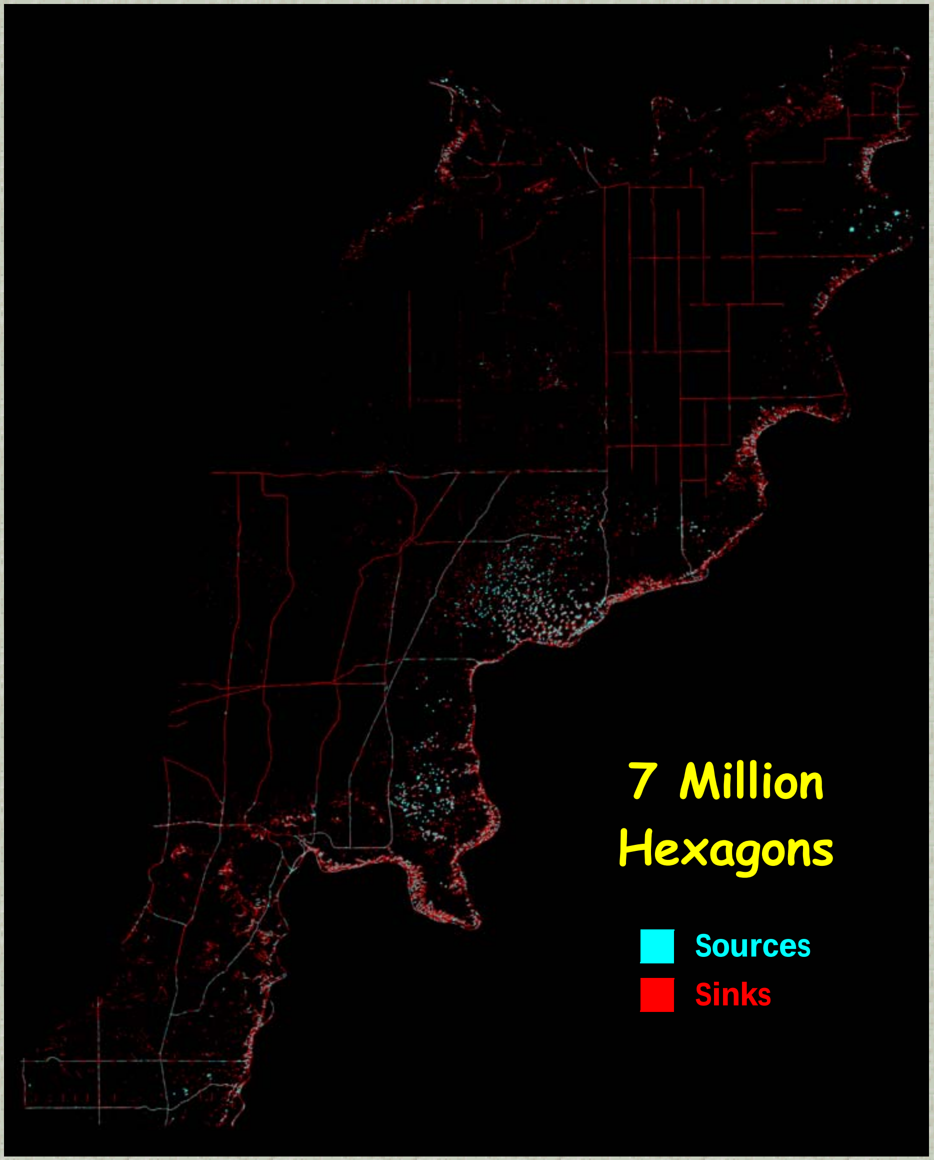
Simulated K-Rat Population Size
Maximum
Mean
Minimum
Population Size (100 replicates)
6000
4000
2000
0
0
25
50
75
100
125
150
Year

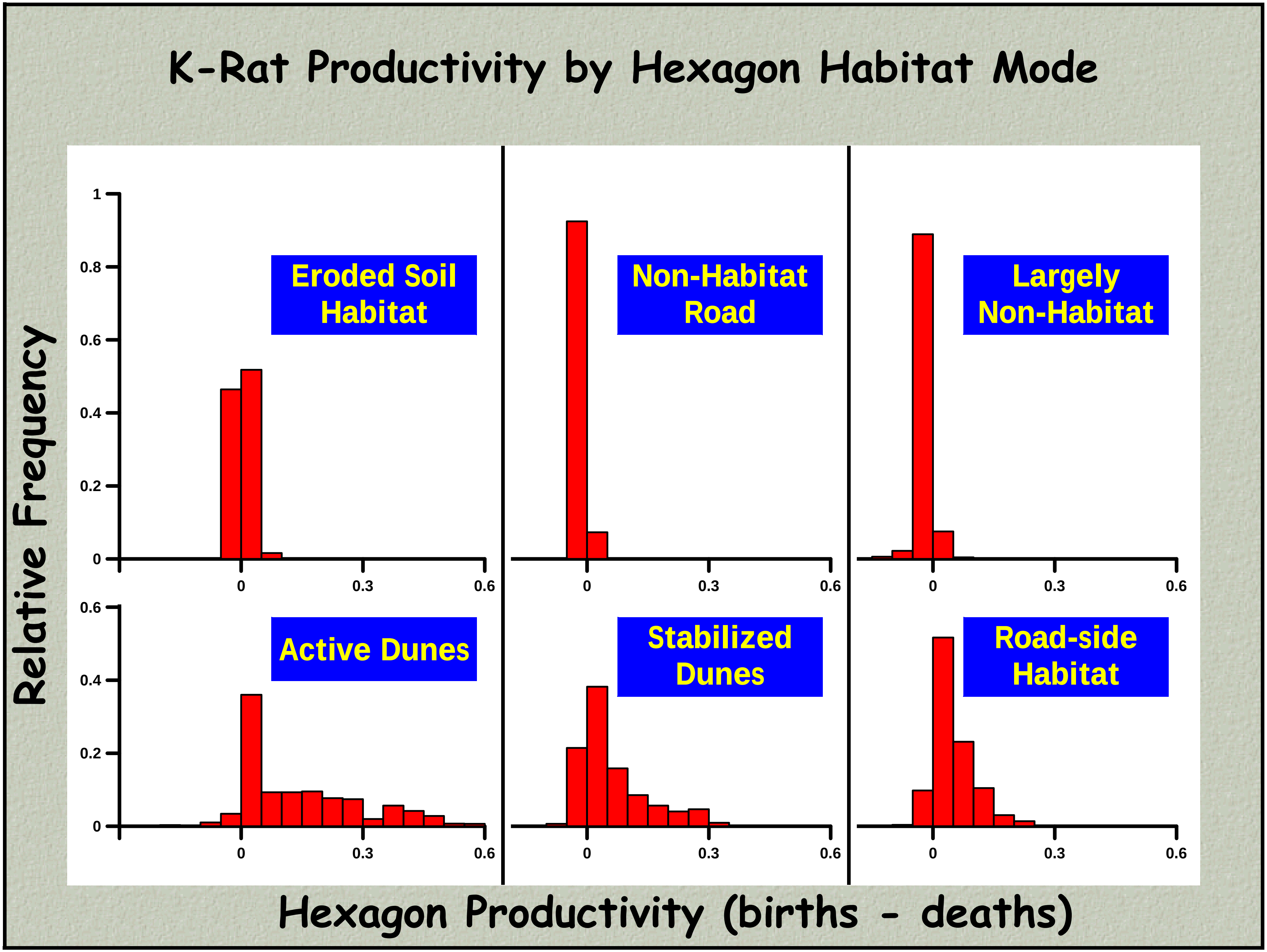

Simulated K-Rat Extinction Rate
(From 100 Trials)
Probability of Extinction
0.25
0.2
0.15
0.1
0.05
0
0
25
50
75
100
125
150
Year

Raster Habitat Map (Model Input)

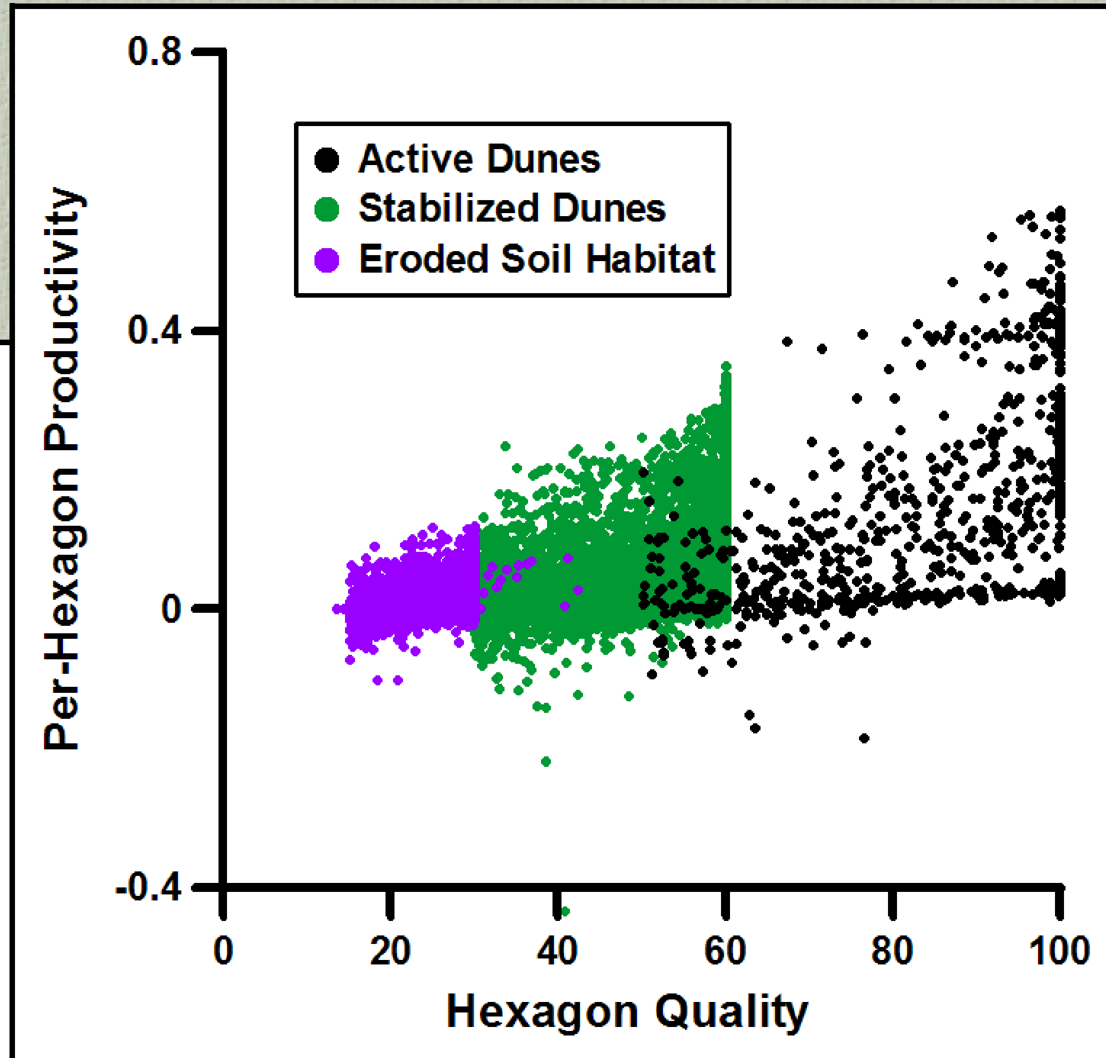


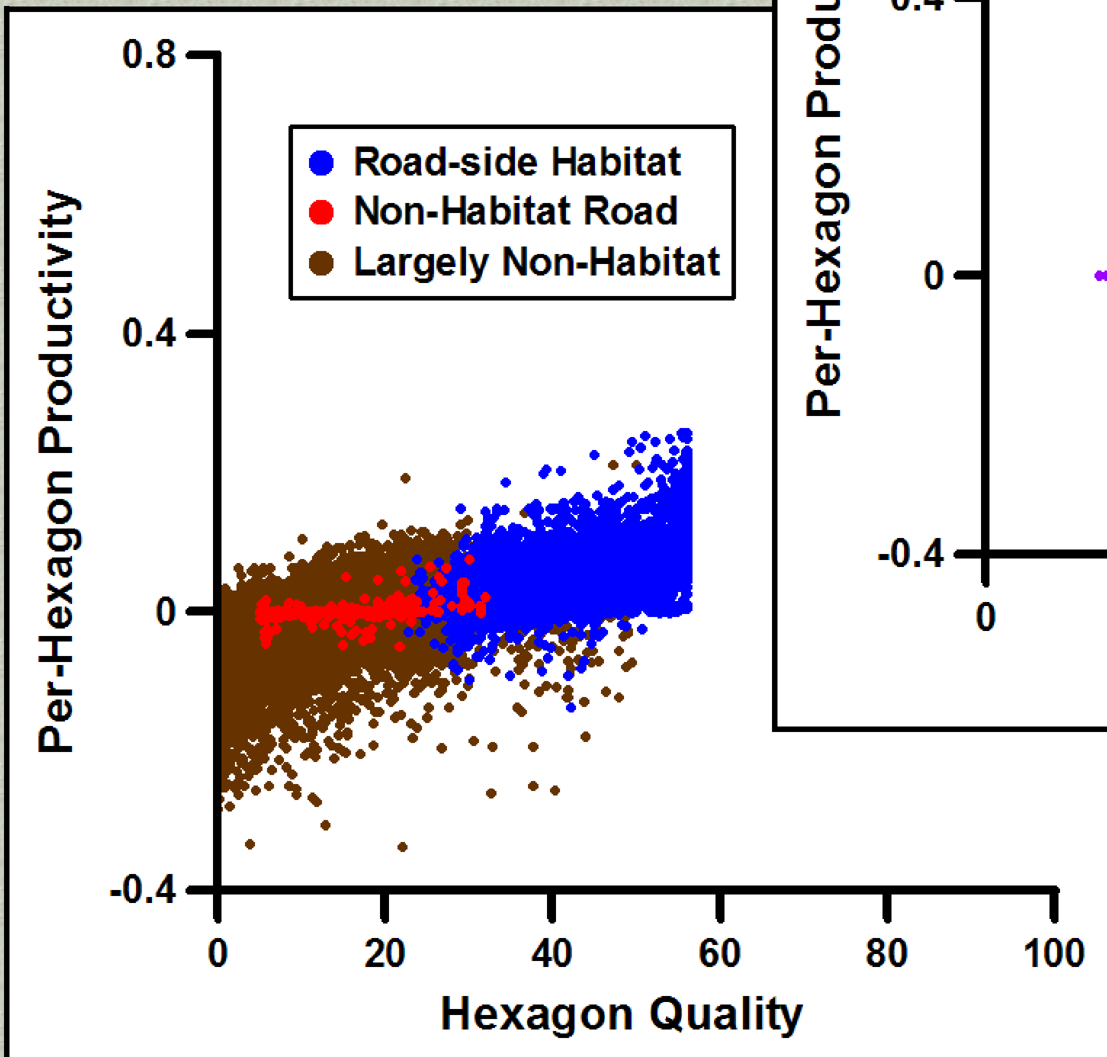
K-Rat Productivity (Model Output)




K-Rat Productivity by Hexagon Habitat Mode
Relative Frequency
Eroded Soil Habitat
Non-Habitat Road
Largely Non-Habitat
Active Dunes
Stabilized Dunes
Road-side Habitat
1
0.8
0.6
0.4
0.2
0
0
0.3
0.6
Hexagon Productivity (births - deaths)

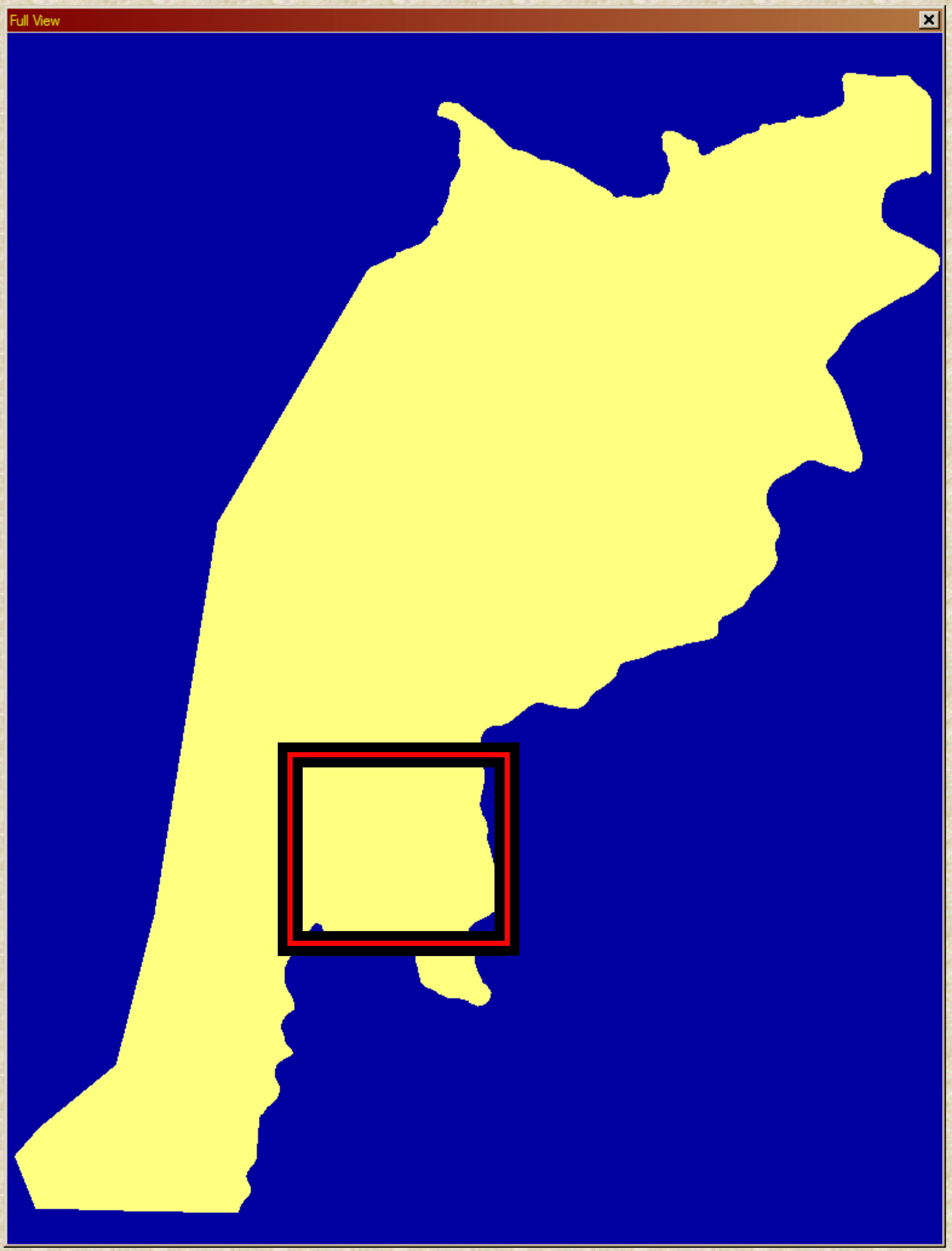
K-Rat Productivity as Predicted by Hexagon Quality





Low Quality Sources ?

High Quality Sinks ?

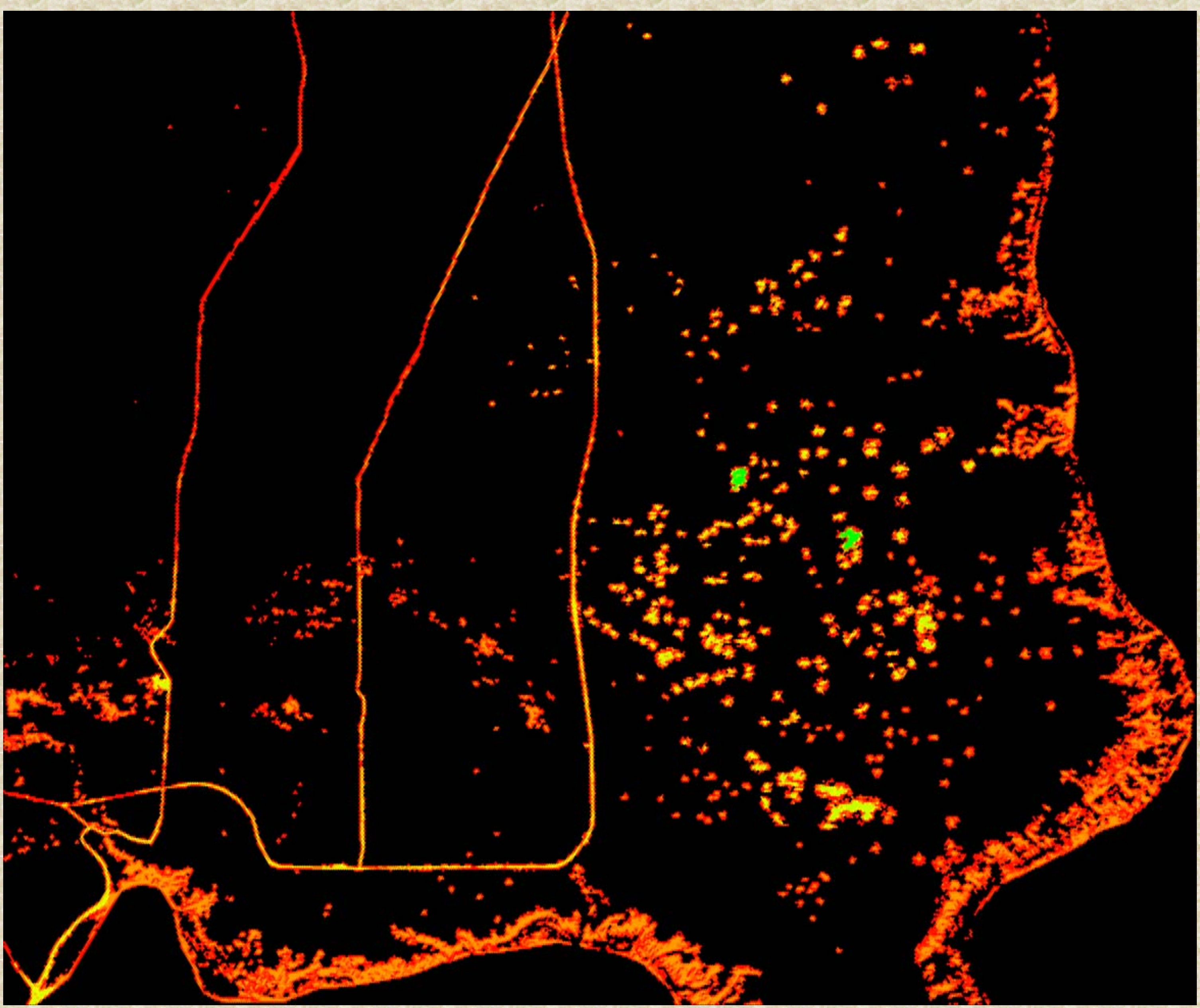


We'll Look More Closely at a Smaller Portion of the K-Rat Study Area

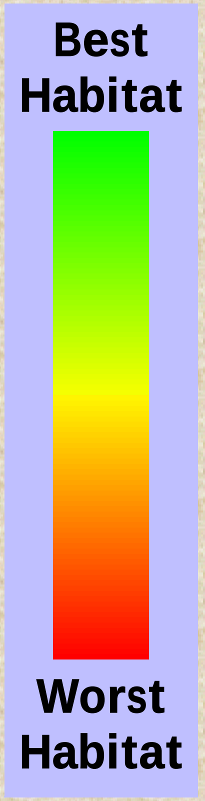
in order to...

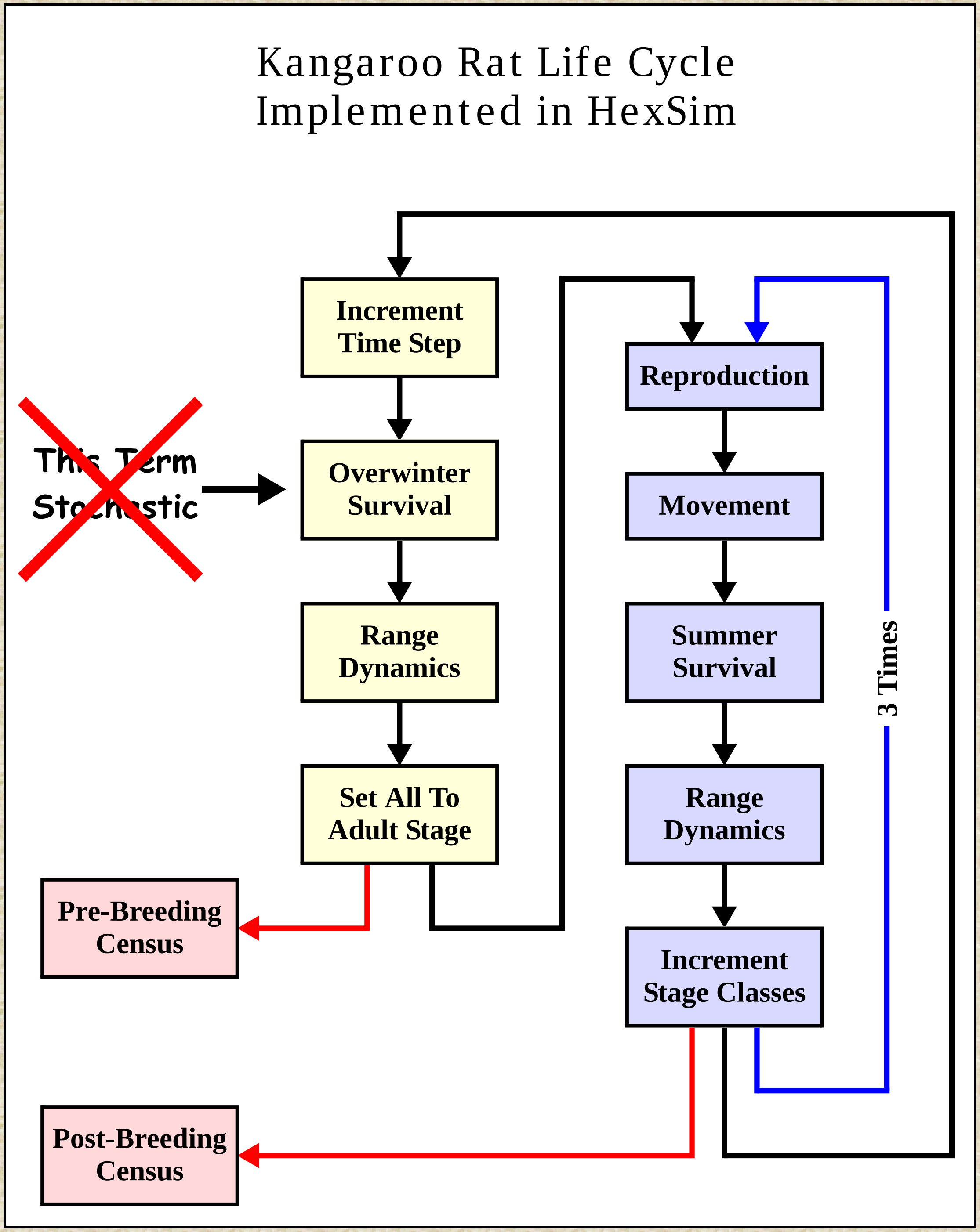
Directly Examine the Consequences of Some Habitat Loss Scenarios

Kangaroo Rat Habitat Quality



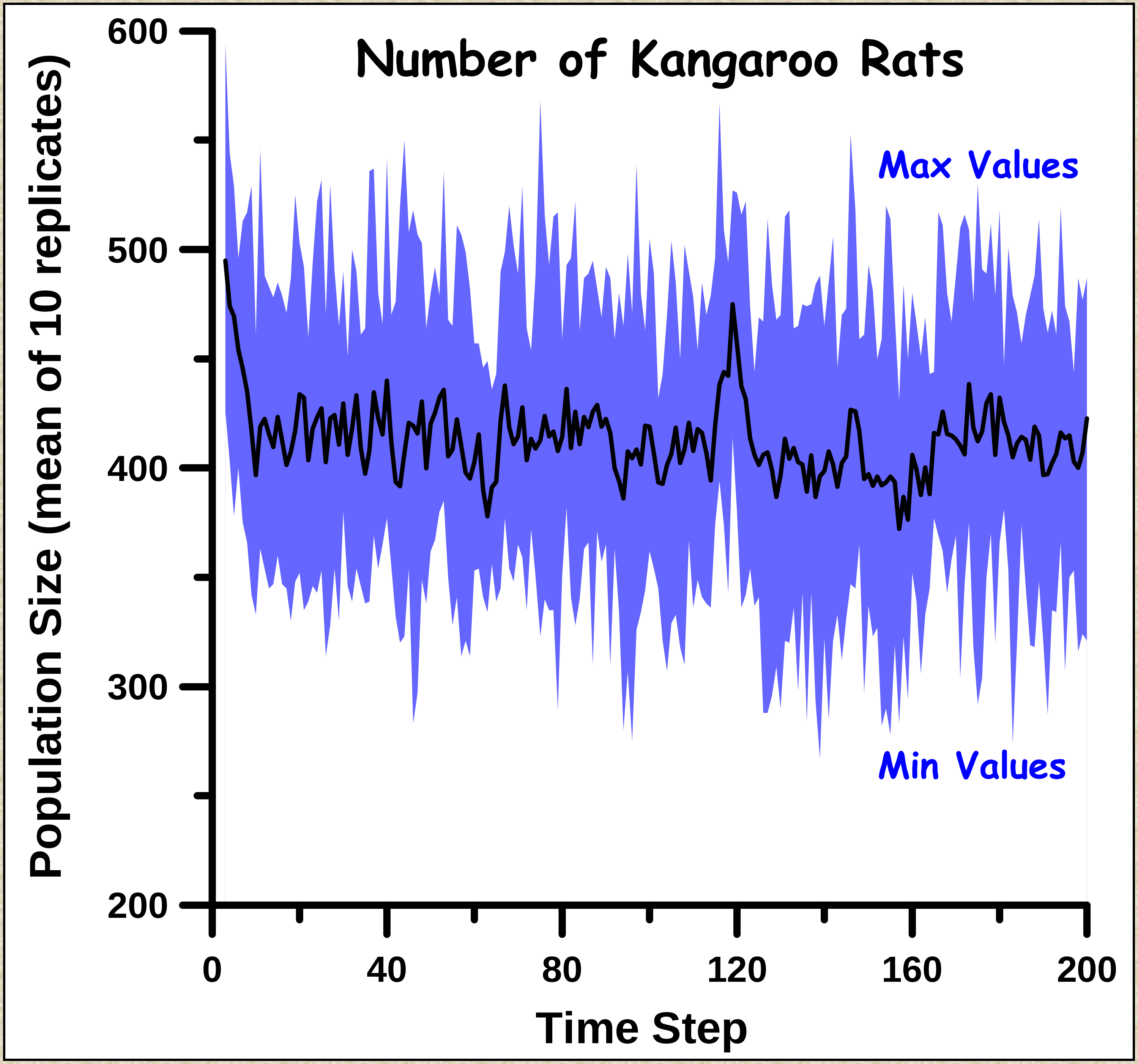
250,000 Hexagons (500 x 500)





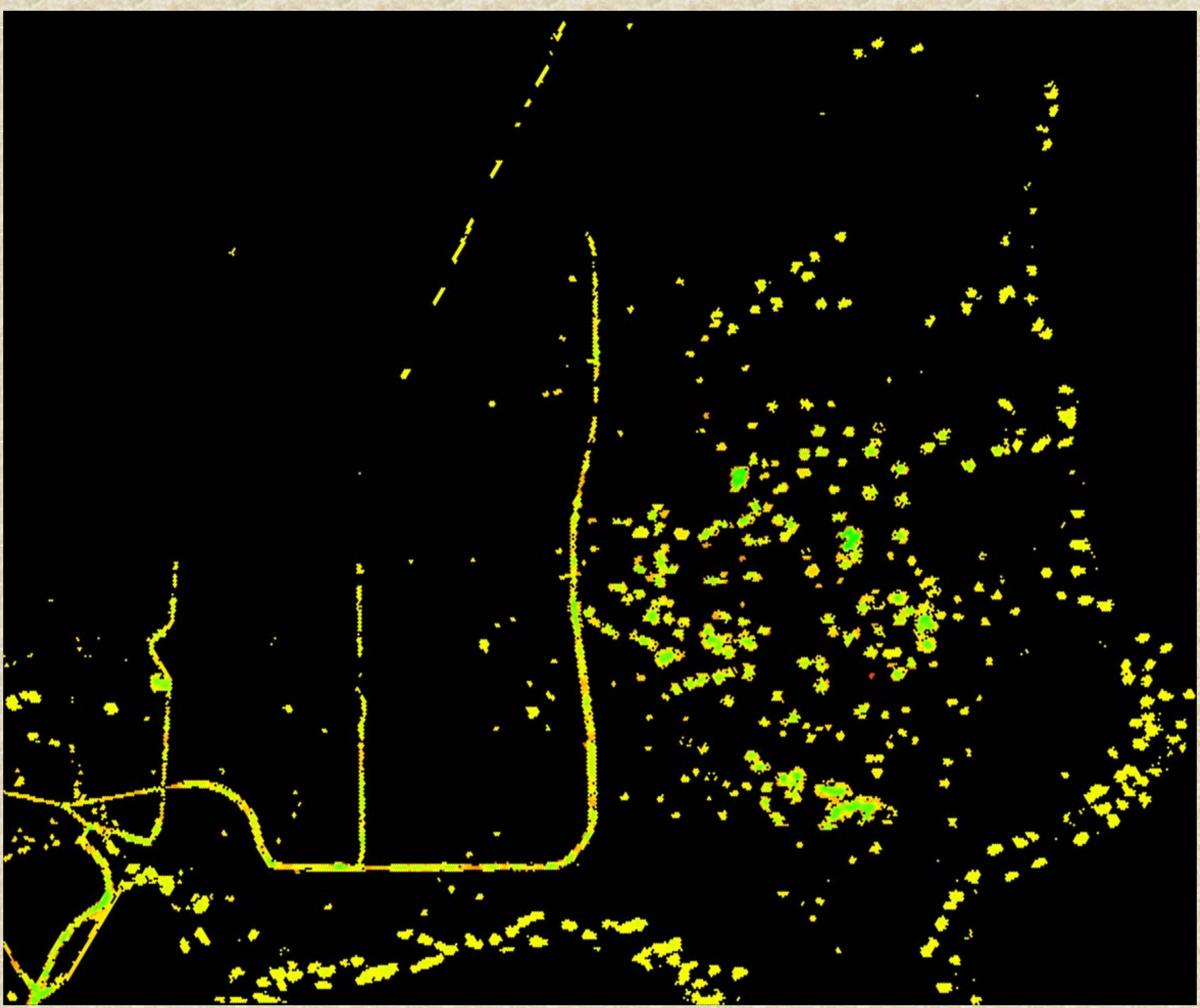
For This Analysis I've Replaced the Highly Variable Winter Mortality With Its Mean

This Will Make Trends Easier To Spot...

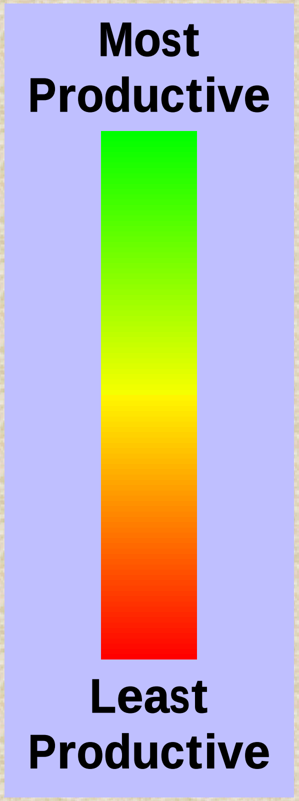


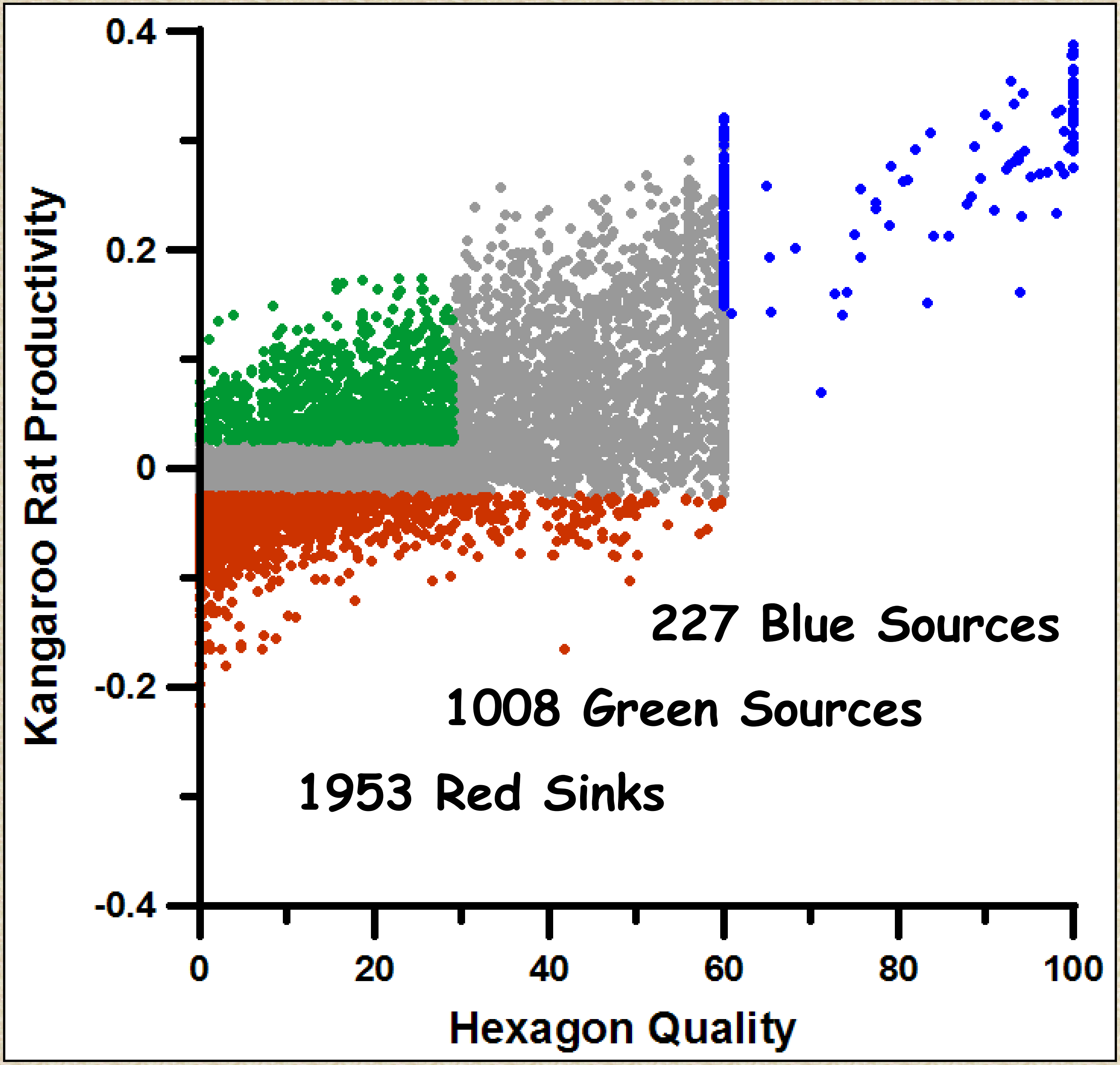
Number of Kangaroo Rats
Max Values
Min Values
Population Size (mean of 10 replicates)
600
500
400
300
200
0
40
80
120
160
200
Time Step

Kangaroo Rat Productivity (births - deaths)



250,000 Hexagons (500 x 500)





Three Removal Experiments

Sum Of Quality Within Removal Groups (color) Is The Same

Results From Removal Experiment
(10 Replicates of 200 Years)

	Sinks	Poor Quality Sources	Good Quality Sources
Number Hexagons	1953	1008	227
Population Dropped By	15%	17%	20%
Hectares To Remove For The Population To Drop By 1%	9.1	4.2	0.8

What Have We Learned From K-Rats ??

Habitat Type and Hexagon Quality Both Performed Poorly as Predictors of Hexagon Productivity

- **Poor quality sites tended to be sinks but there was tremendous variability**
- **Some very good quality sites ended up being quite mediocre sources**
- **But we can use these techniques to develop and then test hypotheses regarding how important specific parts of the landscape are for population stability**

So...

How were these

analyses done... ??

<u>HexSim</u>

A model that's been around
in some form
for about 15 years now...

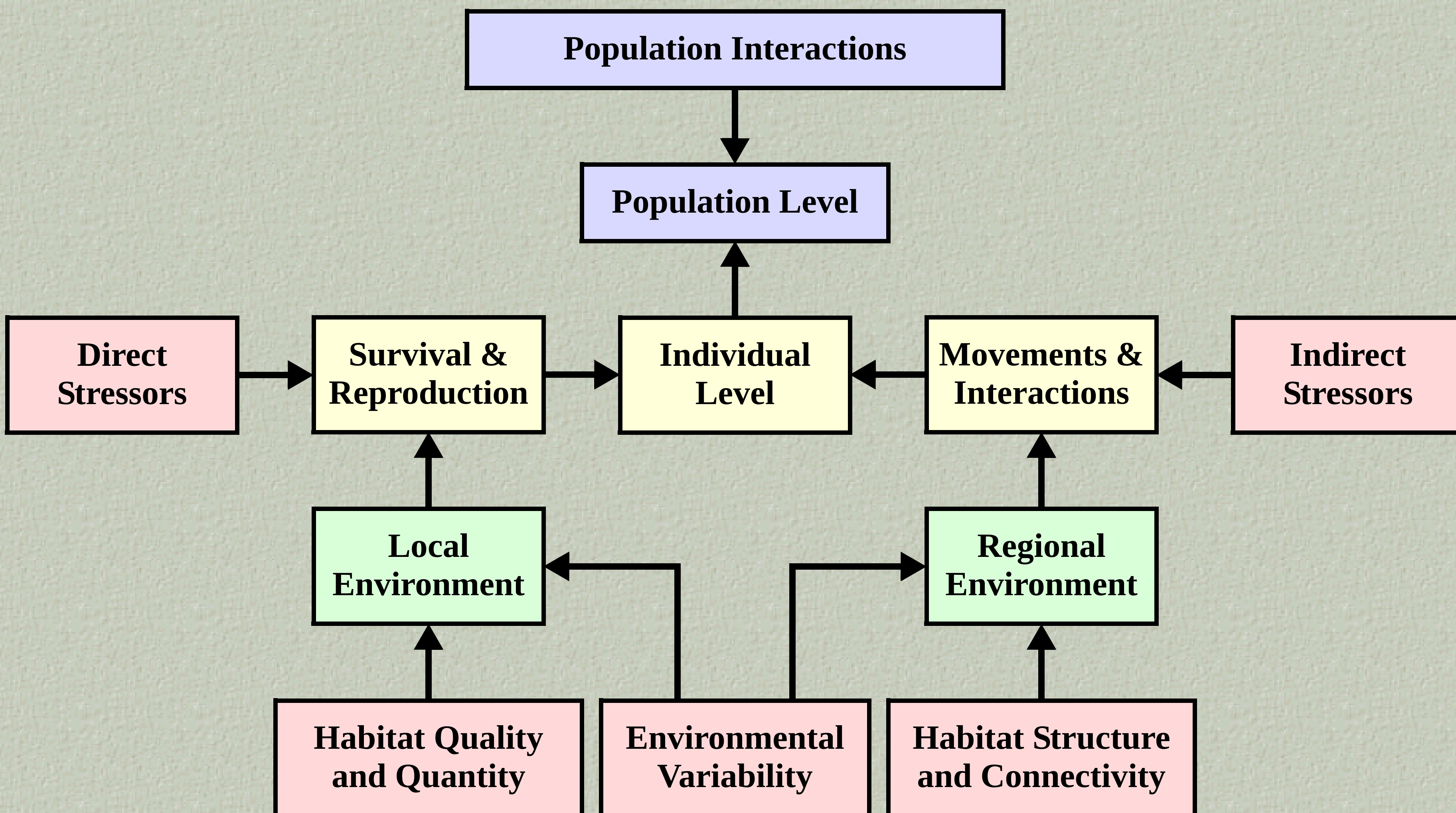
- **Circa 1992**
  Original version was a graduate project
- **1995 - 2000**
  Focused mostly on landscape structure
- **2001 - Present**
  Expanded to multiple species & stressors

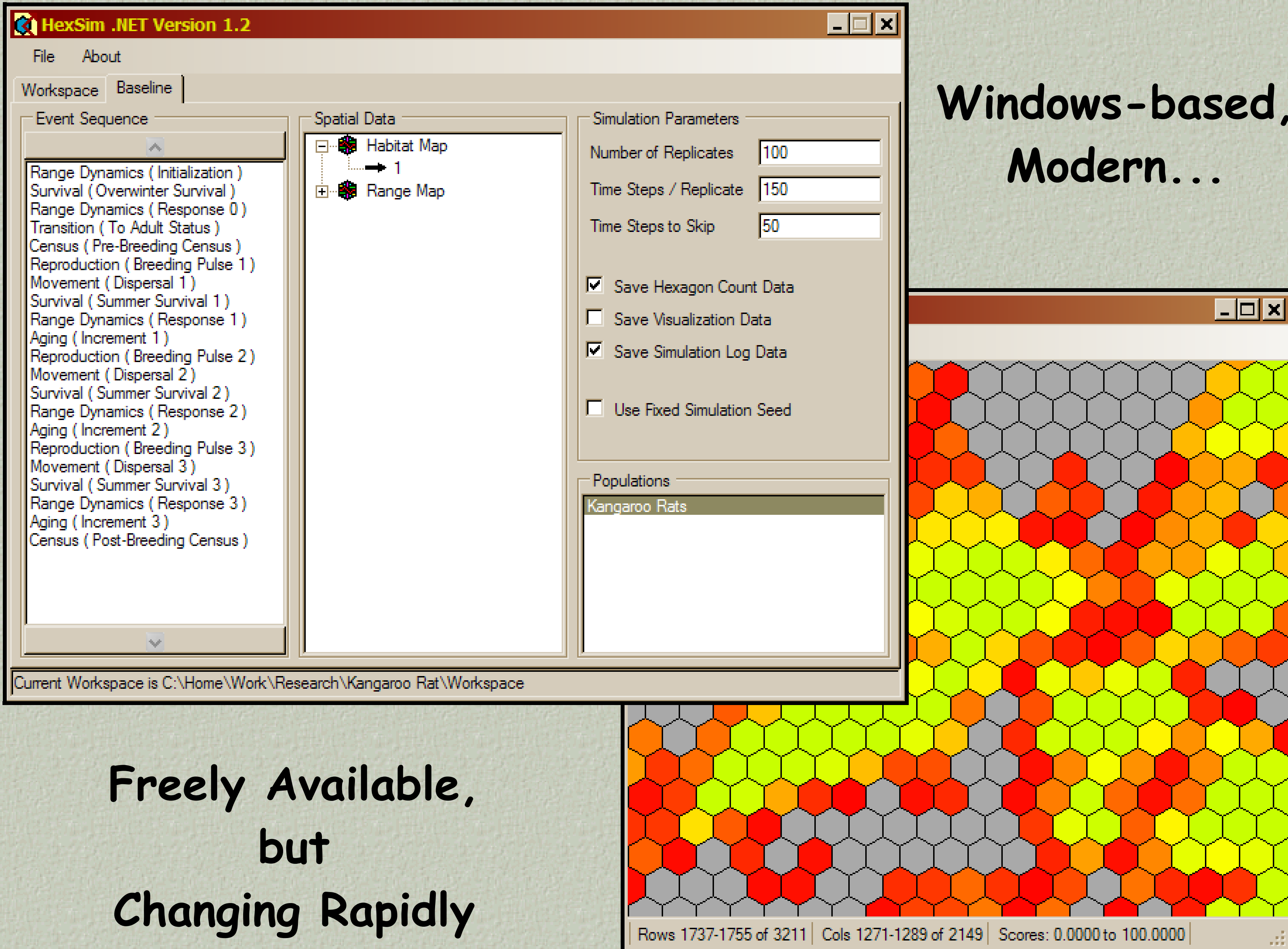
What is HexSim

A SEPM that attempts to balance realism, generality, and parsimony

- **Spatially-explicit**
- **Individual-based (with group dynamics)**
- **Life cycle is user-defined**
- **Individuals can be unique**
- **Populations and stressors can interact**

Conceptual Schematic

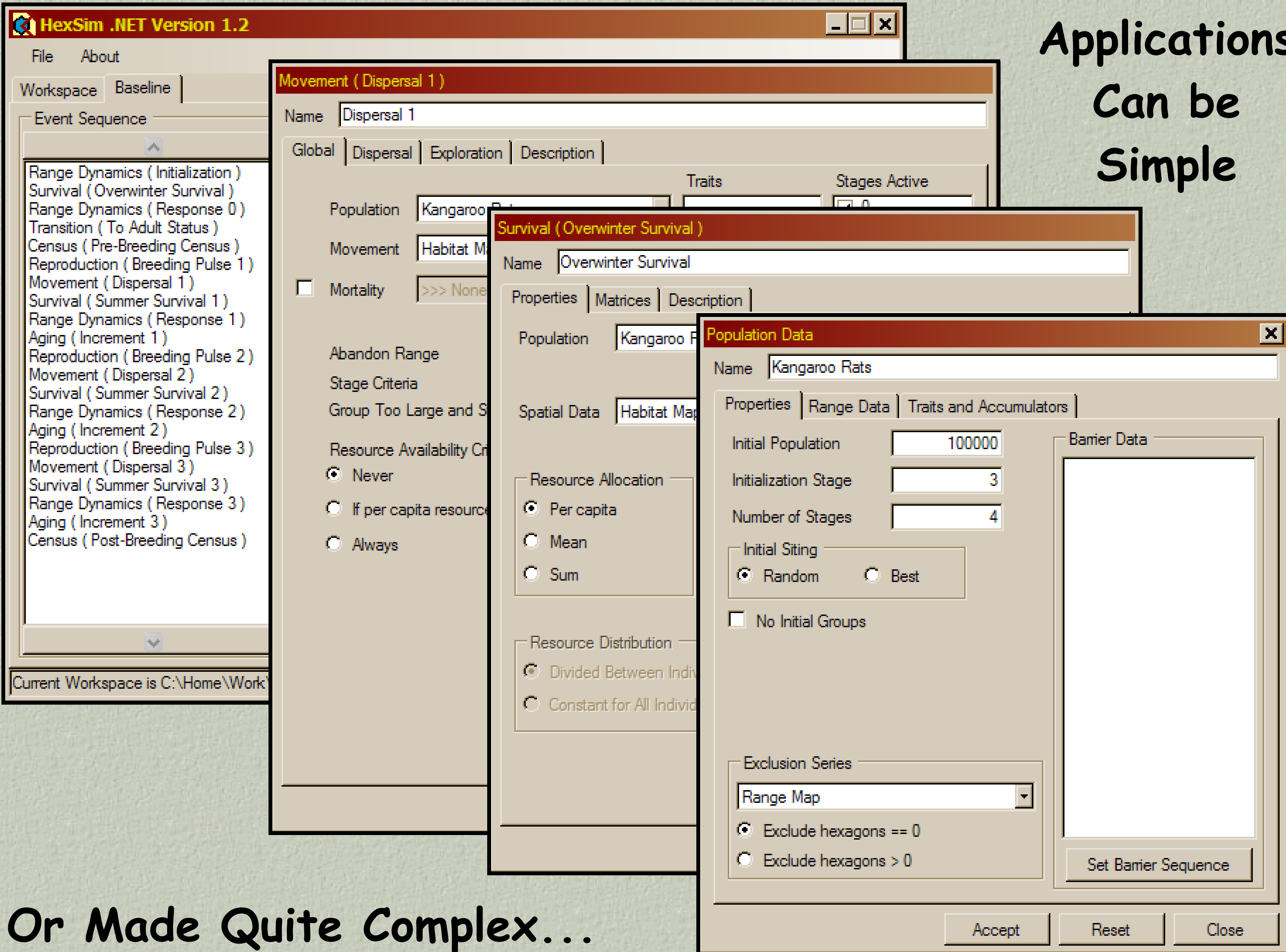




Windows-based, Modern...

Freely Available, but Changing Rapidly

Applications Can be Simple



Or Made Quite Complex...

The model is free

Its ideal for grad student projects

There will be a manual
and a web site
soon...